Master Graduation Project

WEARABLE DESIGN FOR VIOLENT CRIME AGAINST CHILDREN

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Violent Crime Against Children

A report submitted
to the Graduate School of Creative Design Engineering, UNIST
in partial fulfillment of the
requirements for the degree of
Professional Master of Design-Engineering

Kido Chang

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Approved by

Advisor
Joon Sang Baek

Wearable Design for
Volent Crime Against Children

Kido Chang

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Wearable Design for Violent Crime against Children

A MGP report submitted to the faculty of UNIST by Kido Chang

Kido Chang

In partial fulfillment of the requirements for the degree of Professional Master in the Graduate School of Creative Design Engineering. The study was conducted in accordance with Code of Research Ethics.

Graduate School of Creative Design Engineering, UNIST
2017

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Executive Summary

The aim of this project is to define problems and solution regarding violent crimes regarding children. The overall process begins with a preliminary research to gain holistic understanding of the design domains.

This stage involved reading of literatures of studies and reports on the topic, gathering and analyzing of actual crime cases, and expert interviews. An integrated framework of sequence and experience of victim was created as the result. The researcher was also able to understand and grasp the characteristics and patterns of crimes against children. Children are significantly more vulnerable in their ability to recognize and respond to crimes, and often had hard time in giving accurate and adequate testimony. Criminals often take advantage of these vulnerabilities and that is why crime against children easily become habitual and concealed. A benchmark was conducted on the presently available solutions on the market as a part of the preliminary research. Most of the existing solutions were heavily dependent on the judgment and response of the user, which children fall short.

Based on the findings of the preliminary research design goals were set. First goal is to aid response of the children and second is to aid recognition of the guardian. A police officer during her interview has stated that in 90 out of 100 cases, children under 12 would simply cry when they encounter crime. Therefore, the target user of this project was set to children of age 5 to 11, which includes children from pre-school to lower grade elementary school.

Discovery of a set of data types is crucial in recognizing crime situation. A wearable device may utilize various types of sensors to gather this data set and translate them to notify the guardian regarding the child's status. Some existing solutions in the market use circumstantial data as well as bio-signals since data from GPS and IMU is not sufficient to recognize desired conditions like seizure or baby crying. It is crucial to find an optimal set of data that is affective in detecting crime situation of children.

Co-design method was used to attain this set of data. Stakeholders – Four experts and two mothers were invited to participate in a workshop that was designed to find the set of data that necessary for successful detection of crime against children and explore functional and morphological requirements of a device for specified purpose.

As the result of the workshop, a set of data was concluded valuable for detection of crime against children: physiological signal (for emotion sensing), geographical location, movement and posture of the body. Translation of the readings on this set of data would trigger the alarm that would notify the guardian that there is a necessity to check on the child's status through video and audio.

Based on the result of the co-design workshop, traditional method of benchmarking, mood board, sketching and soft prototyping was conducted in order to find optimal design solution. Selection of the design was done with consultation of two professors and three graduate students.

The product service system includes a wearable device worn by the child and a smart-device application for the guardian. The device constantly detects the location, posture, and bio-signal of the child. If there is change in the child's status that is beyond the preset threshold, then an alarm is sent to the guardian, inducing a check-up. The guardian then checks the child's status and makes assumptions based on the information of the location, posture, and emotion data translated from the bio signal. If the guardian judges the child may be in danger, then he or she is able to check the child's status through making video call. Any necessary subsequent response can be made through the guardian's discretion.

Two working prototypes were manufactured: One for user validation and another for the proof of concept. Experiment for user validation was conducted with participation of total 11 eight-year-old children. The main goal of the experiment was to find out whether fear recognition using EDA and ECG is valid in everyday environment of children. Three types of data (EDA /ECG/ Acceleration in motion) were collected in four different conditions. (Calm, fear, excitement, physical exercise) The emotional stimulation of fear and excitement induced through the method used by Jang et al. (장은혜, 우태제, 이영창, & 손진훈, 2007) using the audiovisual film used to arouse fear.

Both qualitative and quantitative analysis was conducted to check the validity of the concept based on the data set of three types: location, body movement, and emotion. The check the feasibility of recognizing emotion through physiological signals on daily level, an experiment was designed to check whether fear is distinguishable from other types of everyday stimulations – excitement and physical exercise. The visual inspection analysis showed that there is distinction between the EDA signal of fear and excitement. The repeated-measure ANOVA showed that there is correlation between the stimulation and stages in rate of change feather from EDA signals and all of the ECG signal features showed that all of the stimulations in the experiment was effective.

Although there are definite advantages of the current concept such that the users will be able to respond to danger in faster based on the accurate data and plus many more, a clear limitation of this project is that it involves sophisticated data handling. The personal data collected needs to be interpreted and requires calibration to each individual user, which requires data science and deep learning technology. This project was an individual work of a designer, and product of such complexity usually requires collaboration of good number of team with its members from various expertise. The majority of human resource of start-up companies developing products of similar technology is composed of engineers and data scientists. Future work should be in a form of teamwork.

Keywords: Crime against Children, Wearable, Co-design, Emotion sensing

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1

Introduction

Background

Children are vulnerable to various types of crime that may damage their lives in an irreversible way. Statistics show that in U.S. alone, more than half of youth experience physical violence and the rate is the highest for victims between ages six and 12, one out of 12 children are afflicted from sexual harassment(Finkelhor, Ormrod, Turner, & Hamby, n.d.), and 800,000 children are reported missing every year(Sedlak et al., 2002). Children are the future of the society and it is an utmost priority to provide protection and security for them. Building a crime-free environment for them would nice but too idealistic, and reality is that unfortunate events do occur. When they do, prompt and proper response to a crime is crucial in minimizing physical and psychological damage. The impact of crime experience in early age is devastating and the suffering many times extends to adulthood. Children who experienced crime may suffer from central nervous system disorder, various types of behavioral disorder, lack of confidence, anxiety disorder, panic disorder, language disorder, various types of addiction, and many more. (서울시 아동복지센터, 2014)

Design for vulnerable social group always has been the main interest of the researcher when it comes to user domain. Series of child abduction, sexual abduction, murder, and abuse in daycare center became serious social issue in Republic of Korea (Wikipeda, 2017). Significant amount of both government and civil investment has been put in to solve the matter, yet the research on existing solutions conducted as a part of domain research show that most of them are educational or has blind spots due to characteristic of children and technical shortcomings(윤영탁, 2016). A solution that swiftly and accurately notifies guardian or relevant authorities would help in reducing the chances of children being harmed.

The initial aim of this project was particularly set on the problem of sexual crime against children. However, as the project was progressing, it was evident that the solution for sexual crime can also be utilized for other forms of violent crimes such as physical abuse or abduction, even for incidents like missing child, which is not a crime technically but can devastate a child and the family. Therefore, the scope of the project was expanded to general violent crime against children so that more can benefit from the result of the project.

Design Goal

Child victim has two major weakness compared to adults: Recognizing crime and responding with proper action. If there were a design intervention that could aid the victim in these two major areas, the victim would have higher chance in avoiding such horrible experience or at least minimize the damage.

In this project, the main design goals are first, aid response of user – that is, child, second, aid recognition of the guardian. This process must be done in a rapid manner and based on accurate data. By achieving these goals children have

Design Process

The overall design process for achieving the design goal – devise product or service oriented design solution to aid response of children and recognition of parents during crime situation, is as below. It consists of five stages – domain research, design research, design concept, validation, and implementation.

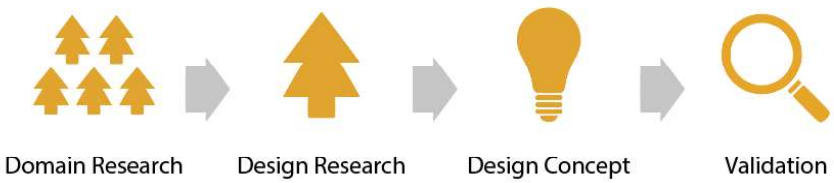


Figure 1. Design Process

In domain research, there was a series of preliminary researches on the design of this project – crime against children. It contains literature search, expert interviews, benchmarking and setting up design goal.

At design research stage, the main part of research is carried out to achieve the design goals. First, the framework for the research is developed in order to carry out a through and focused research, and then followed by a co-design workshop to produce sets of data targeted by the research framework. These data provide design direction for the next stage.

At concept stage, generation and development of ideas took place. Ideation took place with various techniques and based on the selected ideas, more detailed shape and functional features were discussed. For accurate confirmation of design, 3d modeling and renderings were created then 3d printed in actual scale to check the look and feel. Two working prototypes were created based on the design concept, one for validation of concept and another for proof of concept.

Validation stage consisted of an experiment to validate the data set discovered to recognize dangerous situation. The experiment was design with a reference study conducted by Eunhae Jang et al(장은혜 et al., 2007). The experiment took place in an elementary school in Daejeon, with participation of total 11 children, all of same age with, under consent of their guardians. The data that was collected was evaluated with visual inspection of raw data, then extracted features were analyzed with repeated-measure ANOVA technique.

Report Structure

In this chapter, the background and motivation of beginning this project is described. It explains significance of the problems why this design the researcher was attracted to work on them.

In Chapter Two, in order to gain comprehensive understanding of the domain – which is crime against children, different forms of preliminary research were conducted including literature search, case analysis, expert interviews, formation of integrated model, and finally defining of design goals.

In Chapter 3, the main research in order to achieve the design goal was carried out. This process was started by careful planning of research framework, which sets the specific scope of what to look for through the research, and then followed by co-design methodology, which was utilized to extract the desired data from selected stakeholders. Finally, a set of design direction was concluded with the result, which would lead to the next stage – ideation and realization of concepts.

In Chapter 4, process of concept development and selection of final design is introduced. A product service system including a wearable device hung on the neck of a child and software prototype developed for smartphones is devised. For the proof of concept, two different prototypes were created, one for testing the validity of gathering physiological signals in everyday life, and another demonstration for the proof of concept.

In Chapter 5, the experiment conducted with the first prototype mentioned above is described in detail, including the design and execution of experiment and analysis of the result. Analysis is done is various scales: visual inspection, repeated-measure ANOVA method, and qualitative analysis by the venture capitalists.

In Chapter 6, conclusion of this project is drawn and the discussion based on the findings from the validation stage regarding further development of current design concept is stated. Possible improvements of the concept are discussed along with the lessons learned on completion of the project. In the final chapter, expected contribution of the final design is described in various aspects. Then the lessons learned through out a yearlong project and limitations discovered due to the deficiency of expertise and resource will be discussed, followed by future plan considering the limitations found.

2

Domain Research

Preliminary Study Of Crime Against Children

- Literature Study
- Sequence Model
- Expert Interview
- Benchmarking
- Design Goal

2

Domain Research

The design domain of the project includes everything one need to know about crime against children including the target user to contextual information of a crime. Because of the sensitivity of such topic, direct interview of a victim or an observation of an event was not an option. Therefore, most of the research was done indirectly through literatures and collecting second-hand data of reported cases.

The researcher conducted a literature survey and interviews as a way to understand the victim's experience of child crime in detail. In order to analyze and integrate them, a sequence model applying journey maps was established. Journey map is a design methodology helpful in investigating the user's experience in depth. It is to divide the experience into smaller stages, which makes it easier to make findings than only looking at the big picture. Establishing sequence model made it possible to analyze in detail the victim's emotional and physical experiences systematically, and it provided aid in process of design as it organized information visually therefore enabled more intuitive mapping of findings.

A careful and thorough execution of domain research enables to set the project in the right direction with the idea of the big picture and tackle the right problems in applicable ways. Although this stage may seem overly stretched, it is worth the investment.

Literature Study

First, a series of literature search was done to grasp the overall trends and characteristics of crimes against children. This involved watching of movies and documented films on the topic, reading of books and news articles. Then the actual cases of child sexual offenses were collected and once gathered, a total of 35 cases were analyzed using a set of sequence model from existing study (보건복지가족부 & 한국형사정책연구원, 2009)and major variables of sex crime cases. However, existing sequence model lacked detailed contextual information of each stages and more importantly, it was composed from the perpetrator's perspective instead of the victim. Since the target user is the victim of the crime, so a new a new sequence model had to be made.

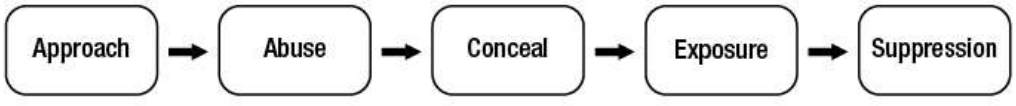


Figure 2. Sequence model by Ministry for Health, Welfare and Family Affairs

In order to compensate for this, we made detailed steps between the stages of the existing model of crime, based on the collection of actual cases, and modified the terms corresponding to each stages of existing model and changed the words to victim's point of view.

Interviews with experts of this field were conducted to obtain the victim's empirical information and for the verification of the new model. Interviews are subject experts (child sexual abuse experts, sexual violence investigators). Through this, we overcome the limitations of the literature study describing the concluded events and the difficulties in understanding the victim's experience, and confirmed the utility of the newly - earned model. They serve to help the victim and identify their situation as close as possible to the victim immediately after the rape case. Through interviews, we analyzed the victim's emotional and physical experiences at each stage of journey map, and extracted the needs and expertise of designers based on them.

As the result of assigning the actual crime case to the newly created model, when the crime is committed by a person of acquaintance, the victim is immediately exposed to the crime scene, skipping certain stages such as approach and luring because the criminal is already within the victim's life radius. Modified and added steps to the sequential model were all based on the collected cases.

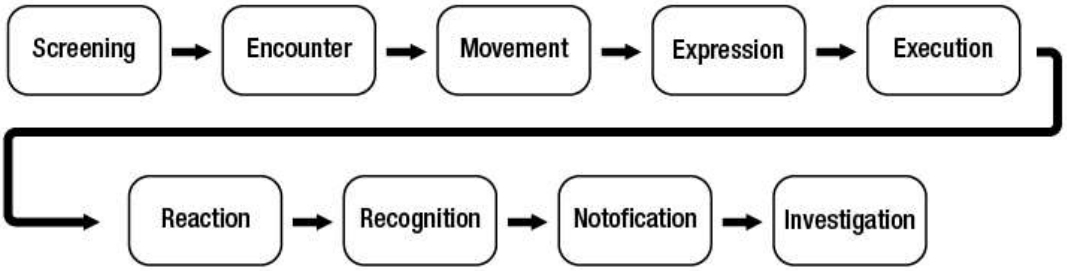


Figure 3. Revised sequence model

Screening: Criminal recognize and selects the victim

Encounter: Criminal faces the victim with attempt to commit a crime

Movement: Process of moving to the different place of comfortable to commit the crime Isolation: The process of making an isolated environment

Expression: Stage in which the criminal discloses intention to harass the victim

Execution: Crime is executed.

Reaction: Response of the victim to the assault including aftermath.

Recognition: A third person with ability to respond (guardians, educators, etc.) are aware of the fact that a sexual offense has occurred to the child

Report: Contacting the police or related organizations

Investigation: Investigate the perpetrators, including the victim's statement.

Expert Interview

The researcher interviewed experts in the field of child crime to verify the newly created sequential model and to obtain detailed empirical information on the victims for each step. Five experts were interviewed: Assistant director of Ulsan Sunflower Center, two clinical psychologists of Ulsan Sunflower Center, a police officer dedicated to crime against children, and a director of Ulsan sexual assault counseling center. Overall, all of the interviewees gave affirmation on the new model while giving detailed information on the user experience on each stage.

Figure 4. Expert Interview

A crucial finding from the expert interview was from the interview with the police officer who stated that 90 out of 100 children would just cry when they confront crime regardless of their level of education on crime situation. This newly gathered information played a key role in choosing specific target user group later on.

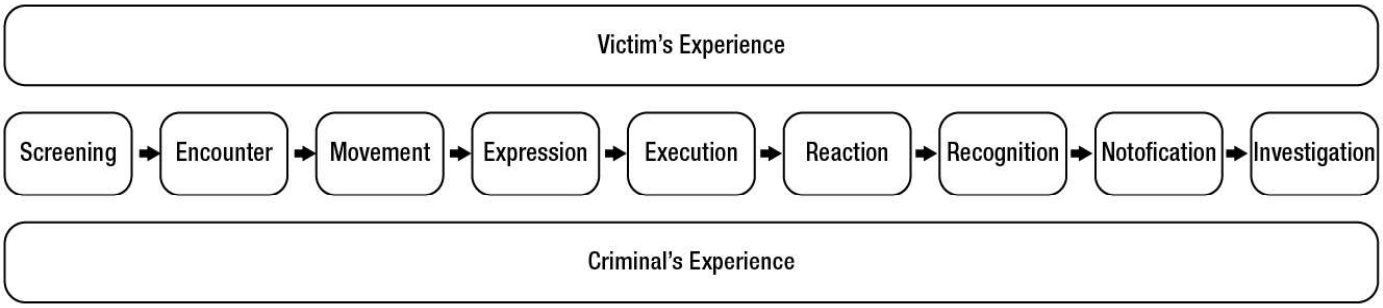


Figure 5. Integrated Model

Benchmarking

There are various existing solutions for children safety and the most popular type in the market is the wristwatch type that provide emergency button that will notify the police when pressed and voice call function with cellular network. They have built in GPS, so that the parents can keep track of children's whereabouts real-time. One problem with such type is that it works only when the child recognizes and responds to the occurrence of danger. It is of no use if the child does not recognize the circumstances of the crime, or fall into panic and fail to press the button as they are instructed. Another problem is that since most of the crimes against children are made within the

life circle of the child, location information alone cannot accurately determine whether the child is at risk.

Second most popular type of solution was a smart-phone application type. The advantage of this method is that it does not need to purchase a separate product but runs on a smartphone only. On the contrary, it is a disadvantage that it cannot be used without a smartphone. In addition, because it is also GPS based, it does not recognize the situation precisely because of the reasons mentioned above.

However, despite the weak points of the currently available solutions, they form up a sizable market, which reflects that there is a definite demand of users and application of newest technology is the current trend. It showed that using right technology in the right place could result in a successful product experience. Because of the benchmarking, the direction of this project was set as a wearable product for young children.

Figure 6. Existing Solutions

Design Goal

Understanding of general characteristic attained by domain research is that children lack ability in three major areas: recognition, response, and testifying of a crime. These vulnerabilities make crime against children susceptible to become habitual, concealed, and reported by third person instead of the victim.

The victims were divided into four categories using quadrant with two axes – one representing ability to recognize and the other representing ability to respond. Type A would include users who have capability to recognize and respond to a crime. A regular adult with such capacity would fall into this category. Users in type A would need a product or service that makes the process of reporting or escaping the situating easier such as whistle or alarming app that goes off when the user triggers the alarm. Type B would need the product or service that informs the situation regardless of the victim's will when a crime is detected. Most children under 12 who feel the emotional stress but does not respond in proper manner may fall into type B. A device that may react to crime regardless of what children do may benefit users in this category. A GPS-signal based alarming app would be helpful to users of this type, yet GPS alone does not adequately fulfill its purpose in detecting danger. Type C includes cases that the victims do not recognize the crime at the time of incident, but the case is discovered later when the victims unintentionally communicate what happened to them. Users of type C would benefit from product or service that helps communicate with their inner circle network

of people. Lastly, cases that victims do not recognize nor the cases are revealed are in type D. Such condition is the worst case when many of the time the crime is buried, and often times when it is discovered, it's too late. Users in this case would require product or service for education, counseling and increase overall awareness to crime of children.

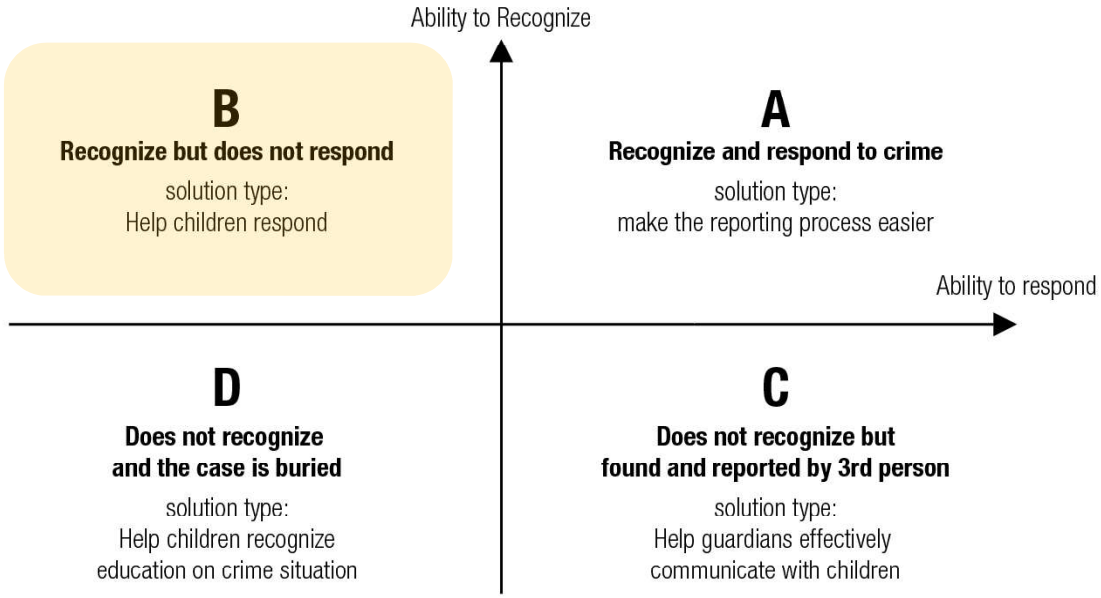


Figure 7. Target Users

Type B was selected as the target group based on its feasibility for solution of a single product based service. In addition, the user group is majority according to the expert interview with crime investigation officer.

Figure 8. Design goals

Since the target group's weak-point is in their ability to respond, the design goal is to set to aid the response of the child, and enhance the recognition of the guardian or the third party that could help. Intervention of an adult with necessary authority is the best responsive measure for the affirmation

of well-being of the child. Aiding recognition of the guardian may also benefit users that fall into the C quadrant.

3

Design Research

Main research on the design goals

- Research Framework
- Co-Design Workshop
- Design Direction

3

Design Research

This section describes how the main part of the research was conducted with formation of the research framework and the execution of the selected methodology.

Co-design, or participatory method was used considering the nature of the topic and how nearly impossible it is to obtain a first-hand data of user experience and the fact that researcher does not have credential in dealing with such sensitive matter to begin with. Co-design is an approach that actively involves all stakeholders in the design process to ensure that the results meet their requirements. Participatory design is an approach that focuses on the processes and procedures of design rather than design style. This technique is used in various fields. It is a way to create a more sensitive and responsive environment for the culture, emotional, spiritual and practical aspects of the users. It is widely used in urban design, architecture, landscape architecture, product design, sustainability, graphic design, planning and even medicine. Also, because the concepts are generated based on the user needs, the direction of the project remain stable. (Steen, Manschot, & De Koning, 2011)

In this project, four experts that currently work with crime against children and two mothers with children with same age as the target user group were invited. The workshop was composed of four phases –warm-up exercise, prioritization of design features, evaluating pre-generated concepts, co-creation of exercise. The workshop successfully produced the necessary data to move on to the next step and was able to determine the design direction.

Research Framework

The purpose of constructing the research framework is to identify in advance what set of data is needed to achieve the design goal, so that no necessary part is left out, and avoid wasting resources outside the scope. It prevents the research from deviating and helps maintain focus.

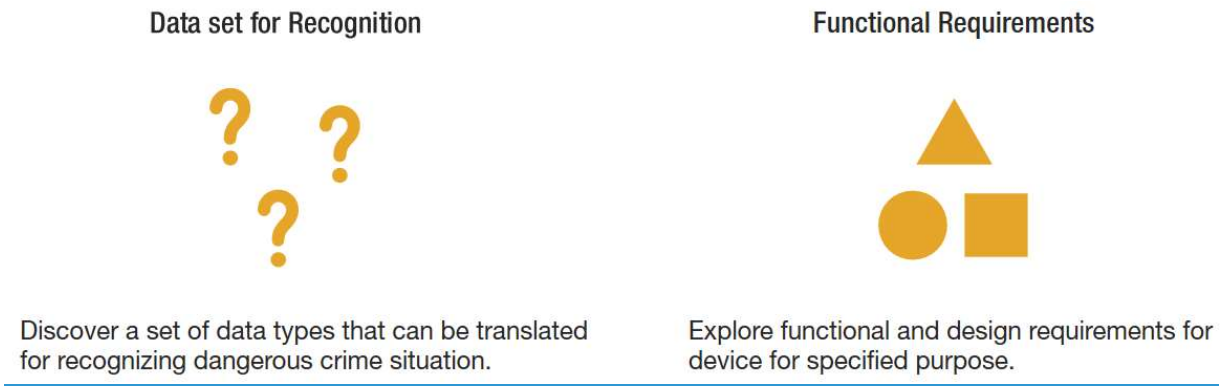


Figure 9. Research framework

First, the researcher wanted to discover set of data and their types that could be translated for recognition of dangerous crime situation. It could a single type of data or a certain configuration of data that work together to enable detection of danger.

Second, if the device was to be used and carried by children, there must be a list of criteria that must be met that suits their characteristic. Prioritization of criteria is particularly important if the device becomes wearable.

Co-Design Workshop

Co-design design method was used to find sets of data planned by research framework. By using co-design method, you can get a deeper understanding of your needs and get ideas that are more creative and reflect user value. It also has the advantage that ideas and concepts are immediately validated by real users, and it is even more efficient when decisions need to be made. Moreover, all this can be achieved with less cost and time. It is also known that from a long-term point of view, user satisfaction is higher than traditional methods.(Steen et al., 2011)

The workshop took place at Ulsan Sunflower Women and Children's Center with attendance of four experts and two mothers. The expert group was composed of one police lieutenant, two clinical counselors, and one sex educator. The two mother both had children with age four to 12. The workshop began with a small introduction about the purpose and background of the workshop and brief explanation of its contents.

1. Warm-up exercise. (25 min)
   To break the ice and get the participants acquainted with the technical features, participants were asked to design a product for child protection. The technical features that are applicable were introduced and they were free to add any function of their own if needed. An advantage of doing this exercise in the beginning stage is that the participants do not have bias formed therefore can be more creative in their idea generation. When they finished, they all went around and shared their ideas along with brief introduction of themselves.

2. Design-feature Prioritization (20 min)
   Participants were asked to create their own priority list with the provided design features in designing wearable devices for children. . Participants were free to add any features they wanted to add in addition to the features provided. Features were provided in physical block shape to allow them freedom to adjust their priorities using their hands. After creating the list, the participants went around one by one, introduced their list, and explained why they organized it the way they did. The provided list was created with reference to three existing lists. (Rheinland, n.d.)(Gemperle, Kasabach, Stivoric, Bauer, & Martin, n.d.)The most important goal of this phase is to identify the elements and priorities that are important to stakeholders and apply them to future design.

3. Evaluating pre-generated Concepts. (35 min)
   Before the workshop, the researcher gathered three more designers including myself to brainstorm ideas through thumbnail sketches. The focus was in quantity rather than quality so that more

ideas were generated in diverse direction. The ideas were chunked into larger categories: clothing type, wristband type, waist belt type, neckband type, clip type, and tag type. By evaluating pre-generated concepts with stakeholders, the researcher was able to grasp pros and cons of each concept with detailed insights about usability and context of the user.

4. Co-design of concepts & rough prototypes (35 min)
   The participants first had 5 minute to ideate on their own. Then they voted to pick the best ideas and grouped up together on the ideas selected. Total three groups worked on the ideas and made rough prototypes with the materials prepared. They put their prototypes on the manikin size of a child. By doing so, they were able to visually see how the solution is worn and used by children and predict ups and downs of the ideas.

Figure 10. Co-design workshop

Design Direction

The data sets planned at the research framework stage were successfully collected as a result of the co-design workshop with the expert group of child crime experts and parents. The data extraction was done through compilation of data from all participants of the co-design workshop.

The data set that was selected by the experts and guardian to be valid in recognizing danger included location, movement & posture, emotion, video and audio. They believed that acquiring and monitoring these data types would ensure accurate interpretation of the situation.

The design requirements for a child's wearable was selected were feasibility in everyday life, light-weight, accessibility, affordability, long battery life, safety, privacy, size-adjustability, and style that suits the preference of the child. The list is in the order of its priority. It was used as it is during the concept generation stage.

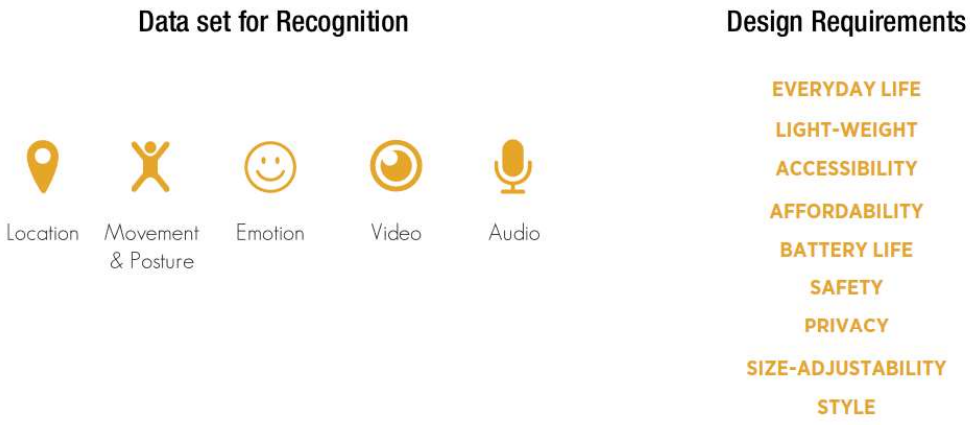


Figure 11. Data sets from the workshop

From the data se for recognition, a more developed design direction was suggested and that was to divide the usage of the data into two stages – suspicion and inspection. Location, movement & posture, and emotional data would be monitored at all time in combined form to more accurately translate child's status, and if there is any suspicious activity then the guardian will receive an alarm to inspect the child's status by video and audio data. The guardian or authority that receive the alarm will make the final call whether the child is in danger or not.

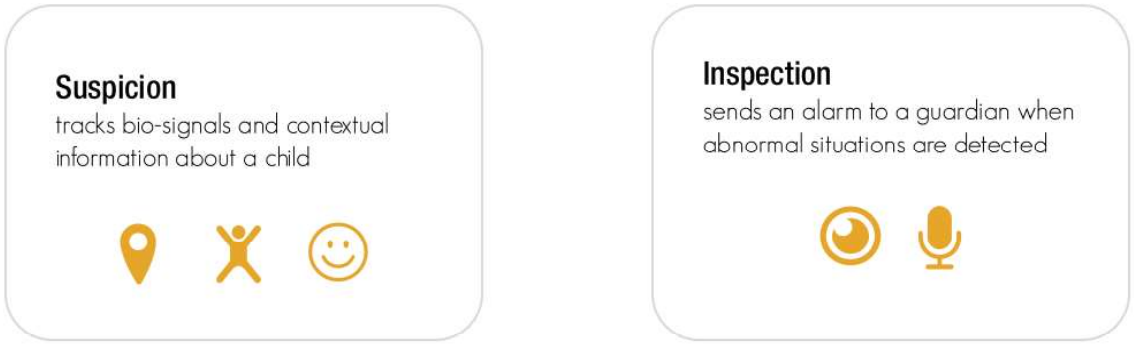


Figure 12. Design direction

4
Design Concept

- Concept Generation
- TinkrBell
- System Design
- Prototype

4

Design Concept

Concept Generation

We performed the ideation based on the design direction established in the previous step. The process of generating concepts consists of ideation stage, where the goal is to generate as many ideas as possible, then concept development stage where most voted ideas were developed further.

Two more of colleagues were invited to generate ideas. During a session, the designers were to draw thumbnail sketches of ideas on a format that was specially made for the ideation phase. The format contains the title of the idea, value for the user, the core design feather, and the technology being used. Mood board technique was utilized to help the process. Mood board is a mediator that helps to explore the emotional areas of products and services. Variety of methods, such as images, words, colors, and typography, is used to form a collection that explains how the final design will look. Traditionally, mood boards are made on large poster boards, but instead, a web-based canvas was used to collect images.

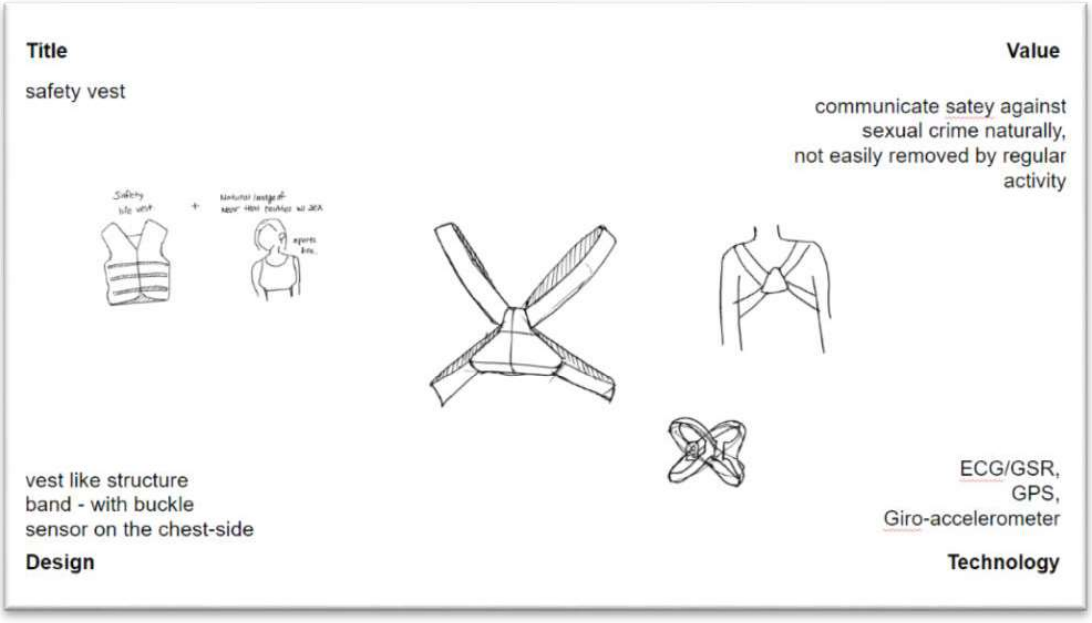


Figure 13. Ideation format

After three iteration of the ideation session, the participants of the ideation casted vote on the ideas and the ideas with most vote was selected for further development. Finally, an idea with neckband-type wearable device was selected for further development, which later we named, the TinkrBell.

TinkrBell

TinkrBell is a wearable device that protects children from traumatic situations such as bullying and harmful events such as sexual abuse. Operating in the background, it constantly monitors a child's biological signals and samples environment data. Live analysis detects potential hazards and alerts guardians or authorities who can then intervene with a live video call or site visit. TinkrBell provides a non-intrusive way for guardians to feel secure about their child's daily activity. It can also reduce the occurrence of traumatic situations through timely alerts and the data it collects can objectively document serious incidents such as crimes.

Figure 14. TinkrBell

The name TinkrBell came from the fictional character Tinker Bell from the story Peter Pan. The image of a fairy that follows the child and keeps company and shine whenever she senses danger was congruent with the functional features of the concept.

Figure 15. Product Service System

There system structure of TinkrBell is described in the figure.

If a traumatic situation occurs, the device detects fear of the user and automatically executes the following functions: 1) alarming guardians, 2) collecting contextual data (e.g. audio, video, time, and location) and sending them to the primary guardian via voice call, and 3) storing the data in a server. The device thus allows guardians to take an immediate action to rescue child and collects evidence of the crime scene.

Activation of TinkrBell creates a subdued feedback that is not provocative to offenders but clearly visible to people around the user. There could be privacy issue regarding on other people who would be in child's radius of daily life. Therefore, the camera lens is physically covered during inactivation. These mechanisms reduce the concern of potential privacy invasion. The concept of TinkrBell is grounded on scientific studies that measure biological evidences to detect tonic immobility, a natural state of paralysis, which animals including humans enter in the face of extreme fear.

Figure 16. LED indicator and emergency button

In terms of usability, the product is designed ergonomically to fit into the shape of neck. The ergonomic design is useful for not only giving user comfort, but also collecting accurate bio-signals. The device adopts a semi-fit design so that it securely collects bio-signals on the neck regardless of the position or activity of the user without tangling his or her neck. With a ring-type hook, even preteens can easily put on and take off the device. The device supports both automatic response through bio-signal monitoring and manual response through the emergency button on the backside, which makes the device more reliable. To prevent neck choking, the device employees a safety lock system: if the device is pulled by force beyond a certain magnitude, it is disconnected. The device is technically feasible as it is built upon existing technologies. These technologies are not expensive, making the device affordable to a wider market. The device can be developed as a stand-alone product or an application for wearable devices with bio-signal sensors. In the case of the latter, the price can be even lower.

Figure 17. Technical features

Prototype

The first prototype was designed to test whether the set of data selected can detect a dangerous situation in child's daily life. Therefore, the features of the prototype were collecting bio-signals and motion posture data. The data acquisition system was composed of two main parts: one for bio-signals and the other for motion posture data. The bio-signal were collected using a kit named Bitalino, which is a quasi-Arduino module that is devised especially for physiological signal acquisition. The kit comes with an open source software called open, signal, which allows easy collection and monitoring of bio-data. The data acquisition system for body motion was built using Arduino UNO and configuration of IMU sensor (SZH-EK065) and Bluetooth module (SZH-EK010). All of the data were collected in raw data

format, which results in rows and columns of data in text files, which later needs further process for analysis.

The second prototype is the proof-of-concept prototype. The purpose of the second prototype is to convey the concept to the public more accurately. The proof-of-concept prototype consists of two units – control unit and wearable unit. The reason for having two separate units is due to technical limitation in putting all the necessary components in small compartment on the neckband. The control unit contains XR-Duino module that enables for Bluetooth video communication in serial-communication, EDA sensor, IMU sensor, GPS module.

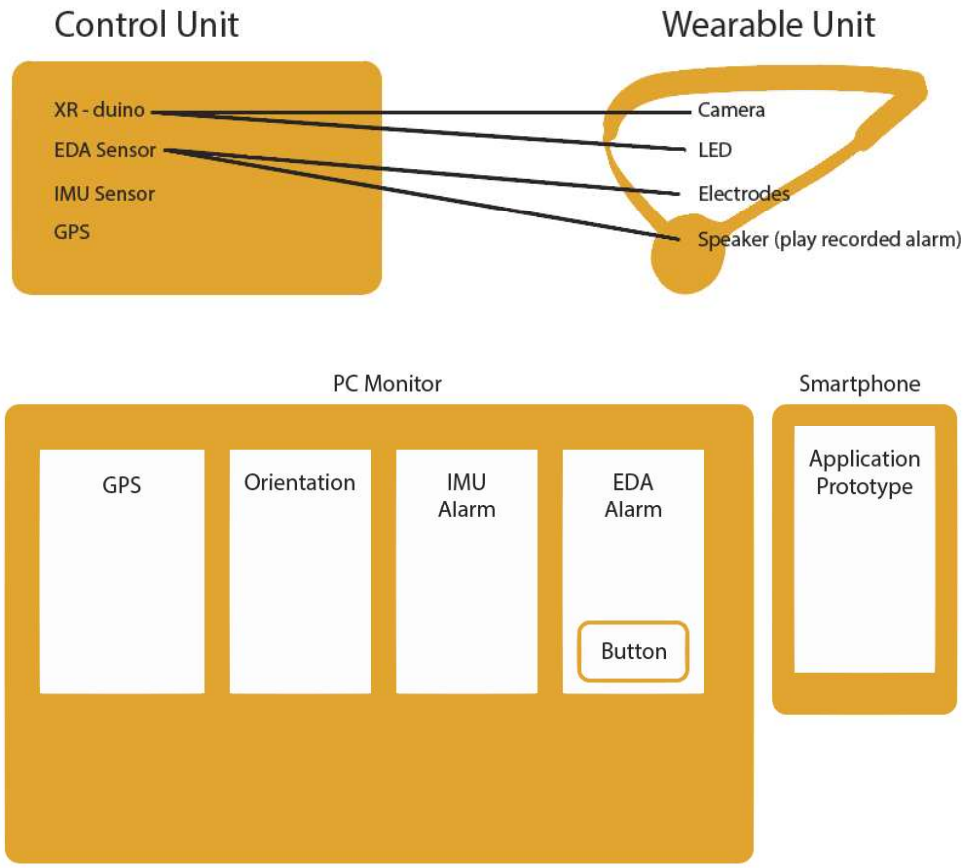


Figure 18. Components of proof-of concept prototype

The wearable unit contained camera, LED, electrodes for EDA signal, and speaker. Data collected by the prototype is displayed on a PC monitor through Bluetooth wireless communication. The main feature of the prototype: 1) GPS, EDA, IMU monitoring. 2) Show alarm whenever there is abnormal activity in EDA or IMU. The threshold for abnormality was set by the rapid change in acceleration for IMU and rapid change in EDA signal. The threshold value for IMU was if the acceleration in any direction of axis (x, y or z) is greater than 400, and the value for EDA was change in amplitude of 120 within 50 periods. These values are different from the actual values to be used for they were demonstration purpose. 3) Live video footage from the camera on the wearable unit. 4) Button

interface to trigger the audio file to play. The audio file contains a warning message for the criminal attempt. The data flow of the proof of concept is explained in figure below.

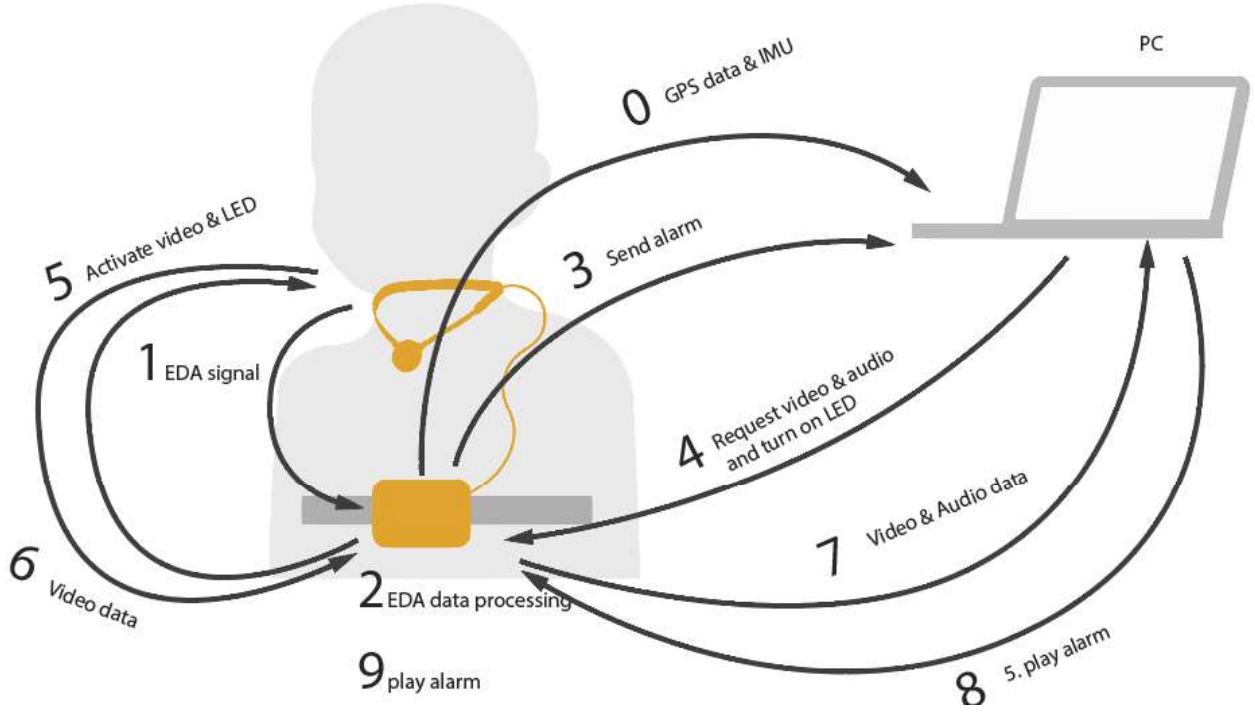


Figure 19. Data flow

The wearable unit is constructed with three different materials – metal, silicon, and ABS like 3d printing material. Rhinoceros, a 3d modeling software, was used to model each parts then they were each laser cut, molded, and 3d printed. The color on the silicon was applied prior to the molding process on the silicon mix, Panton color 3514C was used as reference color. The steel plate was sanded with three different grits to make the fine hairline finish, and then bent using pressure around curved surface.

The interior of the main unit of the wearable unit was planned with precise calculation of the inner components and simulated virtually to check for any interference of parts before manufactured.

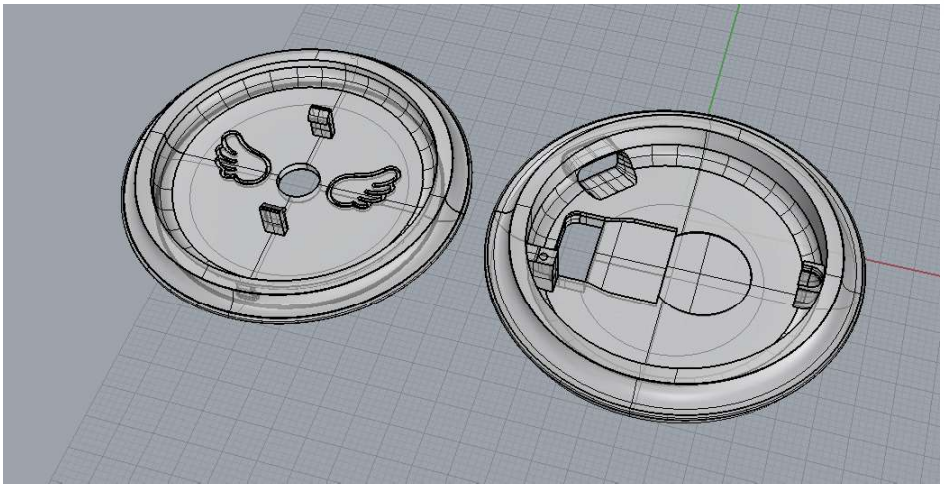


Figure 20. Interior design

A software prototype in the form of smartphone application with interactive features was developed. The purpose of software prototype was demonstrate the functional features and usability of the concept. The prototyping tool used was Proto.io, a web based tool for interactive application mock-ups. It provides various types of realistic interactions and wide-range of freedom in designing the pages. Unlike many other tools that only provides page interactions, it provides object interactions, which allows high precision prototyping.

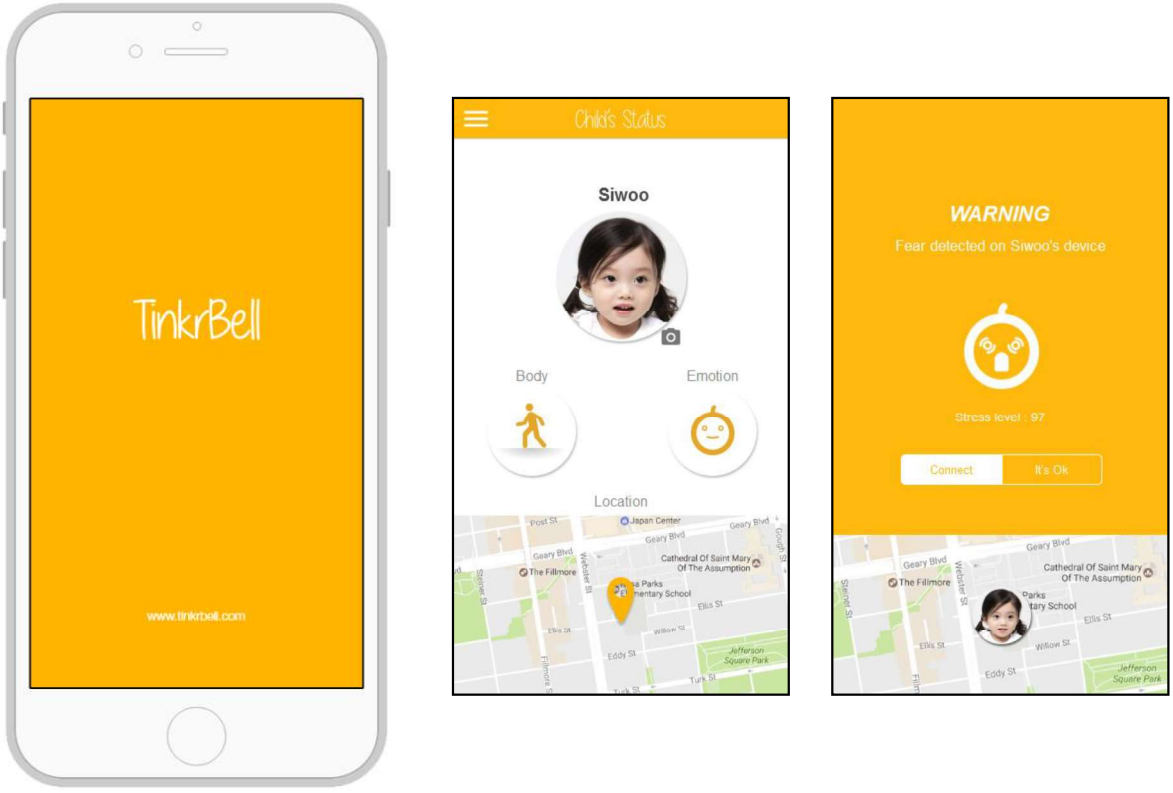


Figure 21. Application prototype

On the start of the app, the user can log in with their ID and password. Afterwards they see a blue screen for pairing their devices through Bluetooth connection. When they tab to continue, they will enter the home screen. The main screen displays the child's status. The user can register the child's name and photo to identify the device to specific child. In the child's status screen, the status data from the GPS, IMU, physiological signals (EDA/ECG) is shown. On the touch on each status, the app will switch to screens where it contains detailed information of the child's location, body, and emotion. Moreover, if there is an alarm going off, the user can choose to connect to the device for video call. Since this is a prototype, change in orientation of the device works as a trigger for alarm and a pre-recorded video footage is played to imitate a video call.

5
Concept Validation

- Experiment Design
- Analysis Methodology
- Result
- Discussion

5

Concept Validation

The entire concept of TinkrBell is built upon the result of the co-design workshop that configuration of location, body movement and emotion data will enable detection of dangerous situations. Unlike location and body movement data, which are already being used widely in various types of devices with GPS, accelerometer and gyroscope, emotion recognition through bio-signals, is still in its infancy, and it is many steps behind regarding commercialization when compared with previous two technologies. It is common that design concepts are ahead of the current market technology level, but that does not mean that technical feasibility can be ignored. Therefore, it is crucial to validate its theoretical basis with rigorous testing measures.

A study on recognition of fear and disgust emotion using audiovisual stimulation by Dr. Jang Eun-Hye and her colleague was used as a reference to design the experiment to validate the current concept(장은혜 et al., 2007). The original study was conducted to examine the psychological physiological responses of children to feelings of negative emotion (fear and dislike). The psychological reaction and autonomic nervous system response (ECG, EDA, PPG, and SKT) were measured after inducing fear and disgust by using audiovisual video in 47 children. The results showed that the emotional intensity (efficacy) experienced by the child was 4.05 in fear and 4.07 in the disgust (out of 5 points). In fearful emotions, the number of skin conduction responses, heart rate, heart rate, respiratory rate, etc. On the other hand, in the dislike emotion, the skin conduction level decreases and the number of skin conduction reactions increases. Based on the results of this study, it was confirmed that various emotions, especially fear, are distinguished from other emotions.

The first step was to conduct an expert interview with Dr. Jang who is currently working in Cognitive Technology Research Team, Robotics in Cognitive System Research Division, Electronics and Telecommunications Research Institute. The main questionnaire of the interview was: 1) Feedback on the current concept, 2) Technical feasibility and technology readiness level, 3) Details of the experiment research. The researcher especially wanted to inquire on how accurate is the emotion recognition when the user is outside lab environment, moving around on everyday environment performing daily tasks.

Experiment Design

The goal of the experiment is to distinguish fear from two appointed stimulated that is expected to bring similar type of change in physiological signals of a child – that is, physical exercise and positive excitement. The same method used to stimulate fear and disgust was used to induce fear, excitement, and a physical exercise to bring the body into exhausted state.

The process of the original experiment was 1) 10 minutes of prep- adhering the electrodes and testing signal collection and introduction to the experiment, 2) data acquisition for 30 seconds of stable

state, 3) 120 seconds of data acquisition of emotional stimulation, 4) 20 seconds of acquisition of recovery state, and 5) survey for efficacy of emotion induction. The new experiment design that was used for this project was a modified version of the reference experiment by Dr. Jang and her colleague. To minimize the order effect, the sessions are divided into two, one emotion stimulation each. The order of the emotion was randomized – if a child goes through fear the first time, then he or she would go through excitement the next time and vice versa. The first session begins with 1) prep and introduction (10minute), 2) followed by data acquisition of 30 seconds of stable state, 3) then roughly 120 seconds of physical exercise (the number of repetition varies from children to children). 4) Then 30second of recovery state, followed by 5) survey for efficacy of stimulation. The participants 5) will rest for approximately 5 minutes for the physiological signals to return to normal state, then the next phase of the first session begins by repeating step 1 through 5, but this time, they will experience emotional stimulation instead of physical exercise. On the second session, the test subject will only go through emotion stimulation.

Both introduction and survey were conducted orally for the participants were too young to comprehend the detailed information in written format. The participant was to score on 5-point scale how effective was the stimulation.

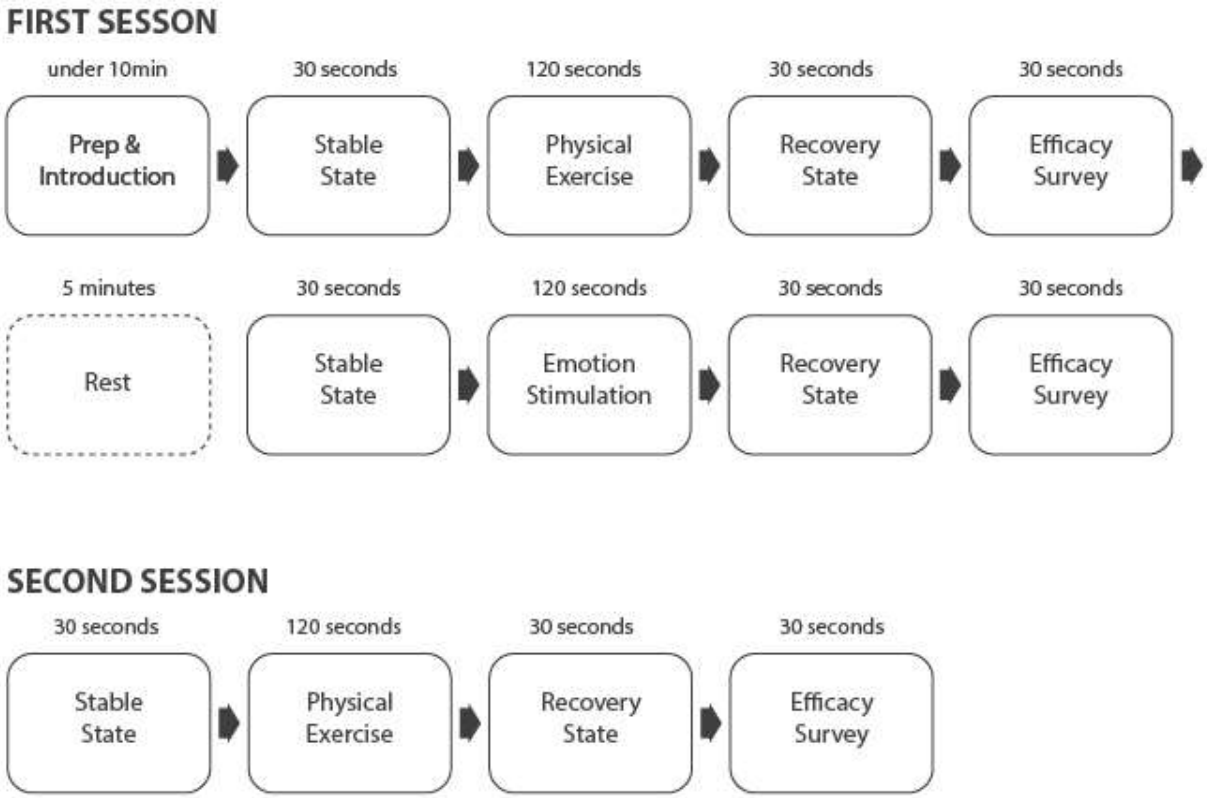


Figure 22. Experiment procedure

The selection of audiovisual material was done with utmost discretion because the stimulation has to be strong enough to raise enough physiological arousal yet must not be harmful to the participant in any way. For that reason, all the horror and thriller genre movies that was allowed for the target age children to watch which was eight was searched using the search engine with filter options of age on the website of Korea Media Rating Board, and made a list of candidate. In addition, a survey was done to 20 children at the same age as the target group. The purpose of the survey was to extract the elements that arouse fear in the participants. Thirteen of the participants have responded that they are afraid of ghosts, seven has responded that they are afraid of zombies and three, sexual harassment. The most watched horror movie was Train to Busan, which is a zombie horror movie that is allowed for teenagers over 15 to watch. It was a surprise that almost half of the respondents has watched the latest horror movie.

For the final selection of the audiovisual materials, clips from a movie was trimmed into 2-minute length. Two of each emotion was chosen for one of each was to be used during the pilot study. Both of the clips for fear arousal contained a scene with ghost, and clip for excitement arousal contained risky, but fun flights taken from animated films. Sit-ups were chosen for physical exercise. The number of the repetition for each participant varied for the goals was to bring the body to an exhaustion where breathing gets rough and start to perspire and every participant has different physical ability.

Table 1. Experiment participants

Female	Male
3	8

Recruiting of participants was aided by an elementary school teacher who allowed publically recruit through a home correspondence paper format. The purpose of the experiment was explained in the document along with cautions of potential harm from participating. Eleven children all age of eight were recruited with the consent of their parents. Three of them were girls and the other eight were boys. All of them were from the same second-grade class and the reward for participating two 10-minute sessions was 10,000 KRW for each person.

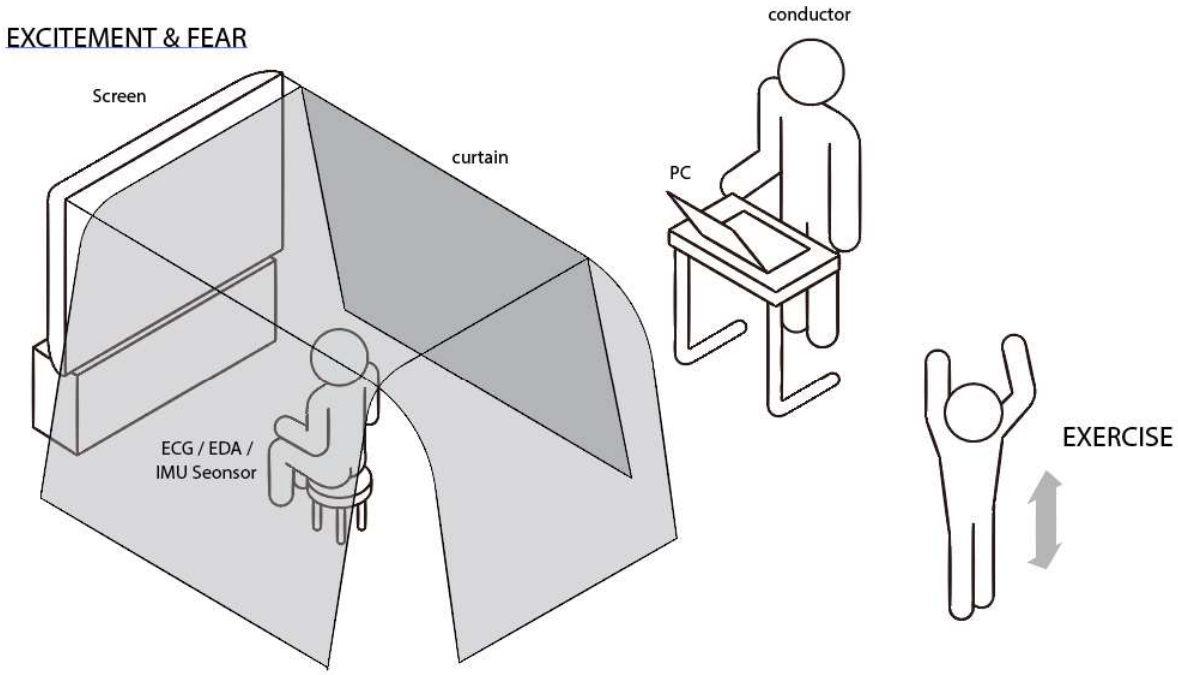


Figure 23. Experiment setting

A pilot experiment was executed in order to verify the design of the experiment. Another goal was to find the proper number of repetitions of sit-ups for an eight-year-old. Through the pilot, details of the experiment were adjusted such as adding curtain over the audiovisual stimulation to avoid outside distractions and minimize reflections of outer lighting source on the display of the screen. The pilot was conducted to one of the randomly chosen participants.

Registration for permission to conduct the experiment to the Institutional Review Board was a pre-requisite of the experiment because the study involves children and potential harm by the stress from watching audiovisual stimulation although it is considered minimal.

The prototype that was described in previous chapter was used for acquiring data from the children. Standard disposable adhesive electrodes were used to collect EDA and ECG signals.

Analysis Methodology

In Dr. Jang's research, she used merchandized solution by medical industry that was not the case here. (장은혜 et al., 2007) To process the acquired raw data, a protocol was required to modify the data into analyzable format. Another study regarding emotion recognition on children using physiological signal was taken as reference. The study was conducted with autistic children under intension of using the mechanism in beneficial way in their education. The researcher of the study conducted an experiment in utilizing emotion recognition for children with autistic disorder for they have deficiency in expressing and communicating emotion. His experiment was done in the living

spaces of the children, not the labs, so he had to go through proper noise filtering and data preparation process and the data acquiring system was similar to that of this project which was Arduino based system with EDA sensor and pulse meter. (Krupa, Anantharam, Sanker, Datta, & Sagar, 2016)

Figure 24. Processing of raw data

The visual inspection was done using Open Signal, an open source software provided by Bitalino. The overall data was inspected for any flaws and abnormality in data. In this process, two of the participant's data had to be dumped.

The purpose of pre-processing the data is to get rid of unwanted spikes and pits and other forms of noises. A low pass filter was used for pre-processing the EDA signal and for ECG signal, a general tapped delay-line filter was used. The features and functions on MATLAB was used to perform overall pre-processing, including the feature extraction.

Because the raw data was in a crude form, they all varied in length. Therefore, the signals were collected 30 seconds from the beginning, 50 seconds from the median, and 30 seconds from the end.

The same features from the reference study was extracted: For EDA - mean, standard deviation and rate of change. For ECG – inter beat interval was calculated by using dynamic threshold function in MATLAB, then mean, stand deviation, and root-mean-square.

When the features were extracted, they were analyzed using repeated-measure ANOVA function on SPSS. All six features were run by 3 by 3 matrix with two dimensions- the type of stimulation and the stage of the experiment. The types of stimulation were exercise, fear and excitement, and the stages were header, median, and tail.

Result

After the initial visual inspection of all the data, a brief form of analysis was made using the average EDA and ECG value of the participants. The duration of raw data varied because of multiple reasons – exercise had to be done in different repetition because the goal was to make the participant physically exhausted, the initiation and termination of data acquisition was done manually. Therefore, the raw data was divided into three stages – initial resting, stimulation, and final resting. EDA, which is simpler type of data, was trimmed and then taken average. The colored section is the stage where the stimulation was applied. Inter-beat interval (IBI) was calculated using findpeak function in

MATLAB, and then the average value was drawn. The values of function had to be finely tuned for every person because every individual had different ECG pattern.

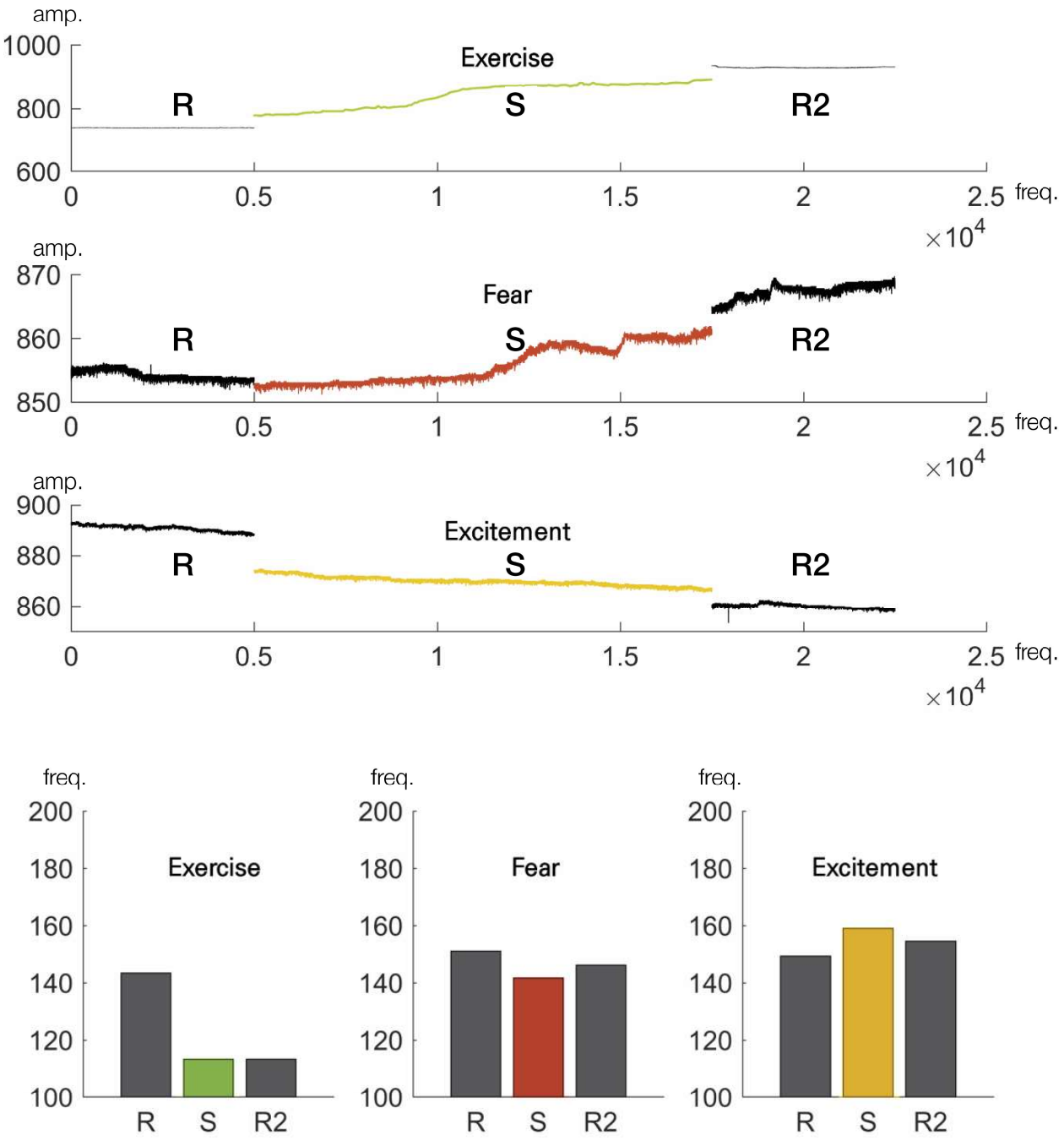


Figure 25. Visual inspection analysis on average value of EDA (top) and ECG (bottom)

A repeated-measure ANOVA analysis was conducted on six features extracted. This was a general analysis of the overall experiment procedure. All ECG data showed strong relationship in between

the stages of the experiment with significance probability of 0.000, which means that stimulation stage is clearly distinguishable from the stable state, and recovery state showing that the stimulation during the experiment was effective. However, there was no statistical findings on the relationship in between the activities from this analysis that the physiological both ECG and EDA signals increase in during physical exercise and fearful stimulation, and decrease when exposed to excitement arousal. The presence of physical motion of body can distinguish physical exercise and fear, therefore in this experiment design, the data can be translated to classify three different types of stimulation.

Table 2. Repeated-measure ANOVA

Data Type	Source	*F*	*p*
ECG_mean	Activity	1.203	0.326
	Stage	338.512	0.000
	Activity * Stage	1.096	0.375
EDA_Change Rate	Activity	3.054	0.119
	Stage	6.805	0.031
	Activity * Stage	0.289 5.497(2^{nd})	0.606 0.047(2^{nd})

For EDA signal, the mean and standard deviation did not give out any statistically meaningful result. Yet, the rate of change showed significance probability of 0.031 within the stages, and 0.047 on the secondary model of activity * stages (analyzing for correlation of activities and stages). This showed that there is significant relationship in the rate of change in EDA signal in between the stages of the experiment and possible correlation of stages and activities.

TinkrBell has gone through a qualitative evaluation by seven venture capitalists, who were invited to give expert validation of the proposed concept and the prototype. The evaluation of these experts may serve as qualitative analysis. There were 10 evaluation criteria in total: (average in the parenthesis)

Table 3. VC evaluation

Criteria	Average score
Is the problem to be addressed well reflects the needs of the people? (8.3)	8.3
Is the problem-solving process reasonably systematic? (7.9)	7.9
Are there useful features, uses, and forms that people would like to see? (7.0)	7.0
Has the technical feasibility of the proposed solution been verified?	7.4
What is the overall quality of result?	7.3
How possible is it for merchandizing?	7.7
How much potential does it have to grow in the market?	7.1
Would you invest in the product?	7.0
Was the presentation well structured?	8.6
Was the presentation well structured?	8.3
Was the presentation and Q&A persuasive?	8.3
Overall	7.7

There were seven products being evaluated and TinkrBell ranked third place with average score of 76.9. The average of the all the products was 76.9.

Positive comments were that the product was targeting the right problem and crucial user need. Yet, there were much constructive comments by the VC that were to be critically accommodated. One of the comment was that there were too many functional features and rather, it should be simplified in its technical specification to be able to have longer battery life. Another VC has said that the form should take something other than neckband to attain a "cool-factor". Many has viewed that the most crucial point for success of TinkrBell is in data acquisition and translation. There was one skeptical opinion that a responsive measure is no use and a preventive measure should be more useful.

Discussion

There were several findings from the visual inspection analysis. First, the pattern of exercise and fear is similar in the sense that they both increase as the participant is exposed to the stimulation. Secondly, in exercise, the signal keeps decreasing when the stimulation is finished, whereas it keeps on increasing when the participant is exposed to fear. Third, when comparing the two emotional stimulations, despite the fact that they are both sitting still, the pattern is contrasting – one is increasing and the other decreasing. Considering that there is a clear distinction between the two emotional stimulation from the visual inspection, and that they both were stimulated under same condition, and that there is significant amount of difference in body movement between the exercise state and the emotion stimulation state, a crude form of observation is made.

Exercise: EDA signal rising with high slope and IBI value of ECG decrease by high magnitude. There is presence of significant body movement. This is obvious because physical exercise will lead to perspiration of body and make the conductance of skin increase.

Fear: EDA signal rising with high slope, and IBI value of ECG decrease by low magnitude. There is presence of significant body movement.

Excitement: EDA signal fall in gentle slope, and IBI value of ECG increase by low magnitude. There is no presence of the significant body movement.

These observations are done on a visual inspection level and therefore need to be checked using statistics. There is possibility that the audiovisual material for inducing excitement was not as effective as that of fear, since the efficacy survey result varies. It was also evident that the efficacy level varied between participants since everybody have different sources of fear and excitement depending on their personal preference or experience. One may find risky flight simulation exciting when another may find musical dancing more exciting. There is limitation in finding one source that suits all participants together.

Moreover, there are countless type of stimulation a user may experience in daily life other than excitement and in order to accurately pinpoint fear, the experiment design must involve real-life observation for sufficient period of time. However, considering that most research on emotion recognition had been done on stationary condition, the attempt to translate emotion compared to kinetic situation had made a meaning finding within its experiment design.

The repeated-measure ANOVA was the only type of statistical analysis run, and it was done on a general level with simple configuration. Applying the findings on the initial findings can be helpful in trying different configurations and analysis methods when working with more advanced capability for statistical analysis.

6
Conclusion

- Expected Contribution
- Limitations
- Design Implications
- Lessons Learned
- Future Plan

6

Conclusion

Expected Contribution

The expectations of contribution of this this project can be made on two dimensions – the product itself and the research behind. The benefits of using TinkrBell is as below.

- Accurate Data: Initiate appropriate response based on accurate information of the child.
- Rapid Response: Increases the probability of avoiding traumatic incidents through a rapid response.
- Evidence Gathering: Supports investigation by providing situational data as an evidence
- PTSD Mitigation: Reduces the recurrence of violent crimes against children and posttraumatic stress of victims by exposing crimes that may otherwise go unnoticed

It came to the researcher's knowledge while investigating studies and solutions regarding emotion recognition using physiological on daily basis, that there is no killer product with reliable functionality. Further development and research on detecting danger through user data including emotion will surely benefit users in various context outside crime against children. Women, the aged, and many other classes of users will benefit from such mechanism along with their families and loved ones.

TinkrBell also can work as a data acquisition tool for big data research. As stated before, various types of crime are sensitive design domains for research for ethical, social, practical issues. If the product spreads to good number of users, the data acquired can be utilized for research purposes with the consent of user, which can be made in the beginning of using the service. TinkrBell has many sensors that can give rich insight about user experience in potentially harming situations, which opens doors for new possibilities in leveraging deep learning and data science to ensure personal safety against crime. A similar type of research was conducted group of Japanese doctors who applied information technology for distinguishing intentional injuries from unintentional injuries. They collected enough data and used data mining algorithm to design a system that has 66% chance of detecting intentional child abuse. (Nishida, Motomura, Kitamura, & Yamanaka, n.d.)

Limitation

The biggest limitation of this project overall is that the project was run only by an individual researcher whose background is purely design. Setting aside the benefits and lessons learned from the journey, there is only so much one can learn in catch-as-catch-can manner. Despite all the effort put

in, there are parts of the project that would have been done better or differently with the newly attained knowledge in the process.

It is repeatedly stated in this report that crime is ethically and socially sensitive topic to be worked with. It is extremely difficult to access quality primary data because it is connected with personal privacy and health. To some people, just recalling a traumatic crime experience can bring significant amount of stress and thus leaving mental damage. This peculiar nature of the design domain restricts the researchers in using traditional methods in design process. Consequently, designers and researchers must invent creative new methods to create data, make user observations, and so on.

A big part of the TinkrBell is data Science. If one search on the web for a list of companies with similar product or service, most of their human resource is focused on data science area. The process requires keen expertise and skills to handle data. Therefore, further development of this concept must be done in collaboration of data scientists and possibly more experts of this filed such as crime or clinical psychology.

To mention another technical difficulty in bringing this project forth was screening the noise in biosensor data. ECG is a signal that is particularly more sensitive to noise of various forms. Screening out noise from the muscular movement during the exercise activity required fine-tuning of filter values on individual level. There were numerous questions on Researchgate.com regarding eliminating noise in physiological signals during physical activities. Seeing from that, the researcher was not alone in the dark while trying to filter out the noise from the raw data.

Design Implications

Through the course of the project, especially during the validation process when the researcher acknowledged the technical difficulties of current solution along with the comments from the expert evaluation, it became clear that the current design has room for improvement. The major reason for choosing neck for the position of the wearable device was because its advantage for acquiring video footage. However, with current technology, neck is not the most optimal place for collecting different type of physiological data. For example, quality ECG signal can only be collected within the premises of chest area. Mediating between different design and functional priorities may result in a more user-friendly solution that is technologically more viable.

Lessons Learned

Throughout the course of this project, this researcher was able to experience that no great work is achieved by one man. Every stage required collaboration with many experts and stakeholders along with the help of fellow designers. Among everything that was done, prototyping with Arduino, data processing and statistical analysis were areas where the researcher had to knock on every single doors that were available.

Internship - The internship program, which was part of the master graduation project, was indeed very helpful in many ways, especially in the sense that it was an opportunity to experience the practice for students outside the academia. I personally spent almost 8 years in studying industrial design in undergraduate degree and my current master's degree program. The company was a start-up company that recently launched their first product and everything there was very energetic and happening fast.

Generating concept under desktop environment was what I was used to and was confident in doing. Years of practice and training has developed a sharp edge in design research and process building in me. However, the practice was all about realization and concrete outcome. I realized that my skills in real-size prototyping for validation of concept needed to be sharpened more.

I was quite surprised by the lessons I learned from the CTO of the company. Although he was an engineer, through the years of experience in manufacturing business. He has worked with numerous designers, engineers and hence, he has become a designer himself in a sense. He had his own know-how's in what is more effective way to test and verify in prototyping other than 3d printing. He also taught me what happens during development of product on the industry level and he job of a designer in the process of manufacturing and I want to express special acknowledgment to him.

Future Plan

Co-work – As previously mentioned it is considered crucial to work with experts from different fields with more defined and organized distribution of labor. Considering that UNIST is a hub for various type of scientific big data and artificial intelligence, it is an excellent place to start the next process for further development. Following are considerable topics for future design and research: Design elements for product service system where decisions are made autonomously. Designing a service system as platform for stakeholders to collaborate for mutual interest – public and personal safety.

Industry experience – Realizing a concept in the market must involve business and manufacturing. Not to mention design is a practical study, it is critical to understand the process of merchandizing a product. The researcher near-term plan is to accumulate industry experience developing abilities to further progress this study. Building relationships with talented people in the industry is also an important part that relates to the plan to collaborate with different experts.

Reference

보건복지가족부, & 한국형사정책연구원. (2009). *(2009 년 제 1 차) 청소년 대상 성범죄자 유형분류와 프로파일링*. 서울 : 보건복지가족부. Retrieved from http://www.riss.kr/link?id=M12475980

서울시 아동복지센터. (2014). 아동학대의 후유증. Retrieved from https://child.seoul.go.kr/archives/151

윤영탁. (2016). 연이은 아동학대, 정부 대책 나왔지만…실효성 논란 | JTBC 뉴스. Retrieved January 5, 2017, from http://news.jtbc.joins.com/article/article.aspx?news_id=NB11203433&pDate=20160330

장은혜, 우태제, 이영창, & 손진훈. (2007). 공포와 혐오 정서에 대한 아동의 심리생리반응 - Psychophysiological Responses Evoked by Fear and Disgust Emotion Using Audiovisual Film Clips in Children. 감성과학, *10*(2), 273–280. Retrieved from http://www.riss.kr/link?id=A75517495

Finkelhor, D., Ormrod, R., Turner, H., & Hamby, S. L. (n.d.). The Victimization of Children and Youth: A Comprehensive, National Survey. https://doi.org/10.1177/1077559504271287

Gemperle, F., Kasabach, C., Stivoric, J., Bauer, M., & Martin, R. (n.d.). Design for Wearability. Retrieved from http://www.ices.cmu.edu/design/wearability

Krupa, N., Anantharam, K., Sanker, M., Datta, S., & Sagar, J. V. (2016). Recognition of emotions in autistic children using physiological signals. *Health and Technology*, *6*(2), 137–147. https://doi.org/10.1007/s12553-016-0129-3

Nishida, Y., Motomura, Y., Kitamura, K., & Yamanaka, T. (n.d.). Representation and Statistical Analysis of Childhood Injury by Bodygraphic Information System.

Rheinland, T. (n.d.). *Smart Wearable Devices Services by TÜV Rheinland*. Retrieved from www.tuv.com

Sedlak, A. J., Finkelhor, D., Hammer, H., Schultz, D. J., Flores, J. R., & Administrator, O. (2002). National Estimates of Missing Children: An Overview National Incidence Studies of Missing, Abducted, Runaway, and Thrownaway Children.

Steen, M., Manschot, M., & De Koning, N. (2011). Benefits of Co-design in Service Design Projects. *International Journal of Design*, *5*(2).

Wikipeda. (2017). 조두순 사건. Retrieved from https://ko.wikipedia.org/wiki/조두순_사건

Appendix

Appendix 1_Expert Interview Questionnaire

아동성범죄 전문가 인터뷰 질문지

1. 간략하게 하시는 일에 대해서 소개해 주시겠어요?
2. 다루시는 성범죄 유형 (성희롱,성폭행..)
3. (통합 모델에 대한 설명과 피드백)
4. 면식 단계 : 범죄자가 아동을 인지하고 범행대상을 선택하는 단계
   A. 주로 범죄의 대상이 되는 아이들의 특징이 있습니까? (예를 들어 아이들의 이동 동선, 외형, 부모님의 맞벌이 유무 등)
5. 대면 단계 : 아동에게 범행을 저지르기 위해 만나는, 서로 대면 하는 단계
   A. 범죄자가 아동에게 접근할 때, 회유 또는 협박 할 때 주로 사용되는 수단이 아는 사람이냐 모르는 사람이냐에 따라 차이가 있나요?
6. 이동 : 아동을 범행장소로 이동시키는 과정
   A. 아동이 범죄자를 따라서 자발적으로 또는 강제로 이동할 때 아이의 행동, 심리는 어떻게 되나요?
7. 표출 : 범죄자가 아동에게 자신의 성폭행 의사를 드러내는 행동을 하는 과정
   A. 성폭행 의사를 표출했을 때 아동의 반응이 어떻게 되나요? (순응한다, 저항을 한다 등)
8. 실행 : 아동을 강간, 및 유사 행위를 하는 단계
   A. 강간 및 유사행위를 할 때 아동이 저항을 하는지 어떻게 하는지 알고 싶습니다. (손을 깨문다, 소리를 지른다 등)
   B. 아동이 저항을 하면 그에 따른 피해정도의 차이가 있나요?
   C. 상습 범죄의 경우 횟수가 반복되는 경우 그 이유가 무엇인가?
   D. 상습법죄가 일회성과 다른 점은 어떤 것이 있을까요? (아동의 저항의 정도가 횟수가 반복될수록 적어진다 등)
   E. 표출-실행단계에서 아동의 심리상태
9. 반응 : 성폭행이 일어난 후에 아동에게 일어나는 일
   A. 범죄자가 범행을 은폐하기 위해 하는 행동들에는 무엇이 있나요?(나올 수 있는 증거와 그 증거를 인멸 또는 은폐하기 위해 하는 일, 아동이 성폭행 당한 사실을 말하지 못하도록 하기 위해 하는 일 등)
10. 인지 : 피해아동이나 아동의 주변사람들(보호자, 교육자 등)이 아동에게 성범죄가 일어났다는 사실을 인지하는 단계
    A. 아동 또는 주변 사람들이 성범죄 사실을 어떻게 해서 인지하게 되나요?
11. 제보, 수사, 재판
    A. 범행을 입증하기 위한 증거수집에서 겪는 어려움이 무엇인가요?
    B. 아동이 진술하는 과정에서 겪는 어려움이 있나요? 있다면 어떤 것들이 있나요?
12. 아동, 지적장애인 대상 성범죄를 예방하는 서비스/제품을 개발하려고 합니다. 어떤 기능이 포함되면 좋을까요?
13. 아동, 지적장애인 대상 성범죄자를 처벌하는 서비스/제품을 개발하려고 합니다. 어떤 기능이 포함되면 좋을까요?
14. 아동의 생리학적 반응(심박수, 체온, 자세의 변화, 떨림 등)을 수집하면서 긴장성 무운동, 스트레스 지수 향상과 같은 신체적 변화가 감지될 경우 (성범죄 현장에서 피해자에게 관찰됨) 이를 보호자나 관련기관에 알려주고, 증거를 수집해주는 장치가 있다면 성범죄 감소 및 처벌에 도움이 될까요?

A. 이러한 개인정보 (생체신호, 위치정보 등)를 사용하는데 법적 제한사항이 있나요?

15. 아동이나 지적장애인의 성범죄시 피해자가 겪게 되는 신체 내 외부적 경험에서 범행 인지 요소를 확인하고자 할 때 대상자와 분야의 특성상 윤리적인 장벽에 마주하게 됩니다. 이와 같은 연구시 어떤 우회 방법이 있습니까?
    A. 기존의 방법 소개
        i. PTSD 환자에게 트라우마에 대한 나레이션을 읽어주고 신체 반응 측정
        ii. 질문 및 설문
        iii. 사례 비교 및 연구

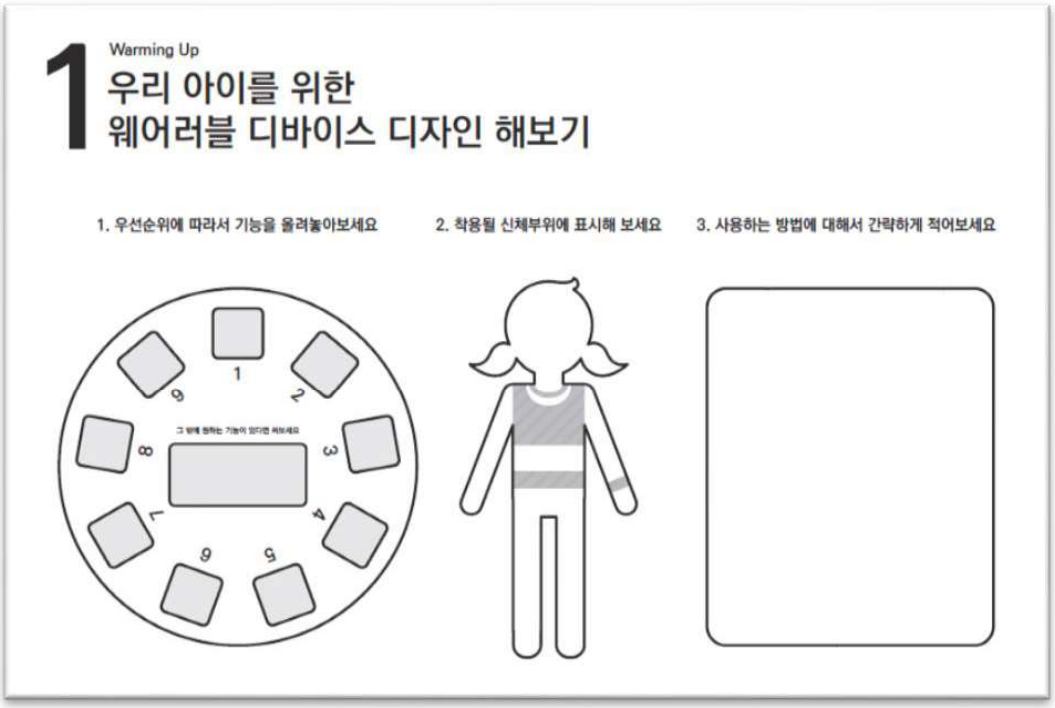
생체신호를 통한 감정인식 전문가 인터뷰 질문지

1. (컨셉 설명을 들은 후) 현 컨셉에 대해서 자유로운 의견을 부탁드립니다.
    A. 현실성
    B. 기술성숙도
    C. 예상되는 효과 정도
    D. 그외 피드백 etc
2. ECG 혹은 GSR 두 가지 신호 중 한가지만 써야 한다면 어떤 신호를 사용하는 것이 좋을까요?
3. 공포나 놀람에 대한 데이터 분석은 무엇을 통해 이루어 지는지?
    A. RAW DATA 의 해석 방법
    B. 사용된 분석 툴과 방법
4. 가만히 앉아있는 실험환경이 아닌 활동중의 감정 측정이 얼마나 정확한가요?
    A. 예: 걷기, 뛰기, 대화, 식사 등
5. 실제 아동을 상대로 공포 상황을 측정할 때의 주의사항에는 어떤것이 있나요?
    A. 피실험자를 어떻게 구하셨나요?
    B. 미성년자를 상대로 한 실험인데 동의는 어떤 방식으로 이루어졌나요?

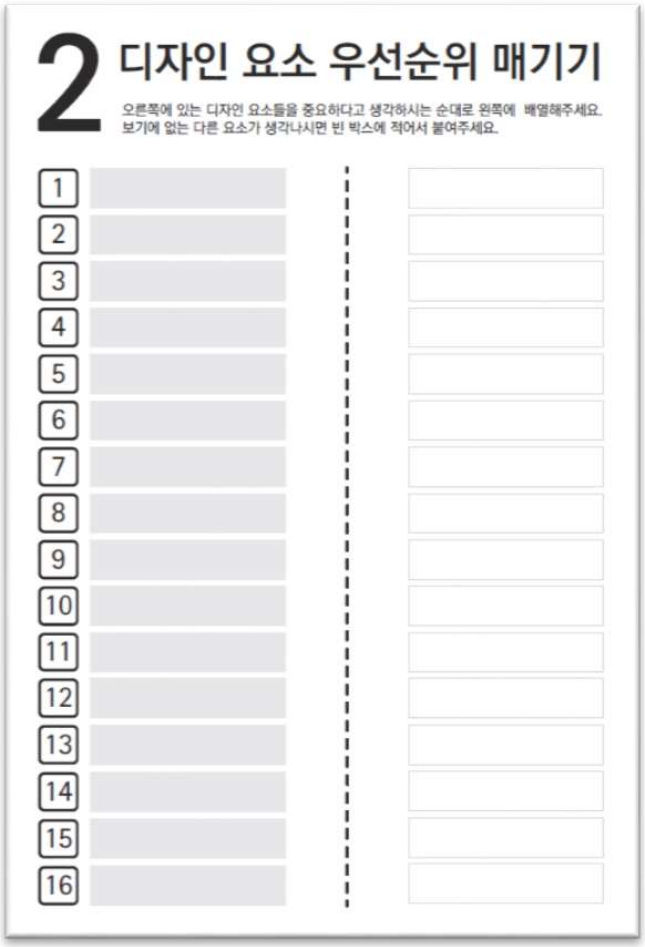
Appendix 2_Co-Design Workshop Toolkits

Functional feature diagram

Warm-up Exercise



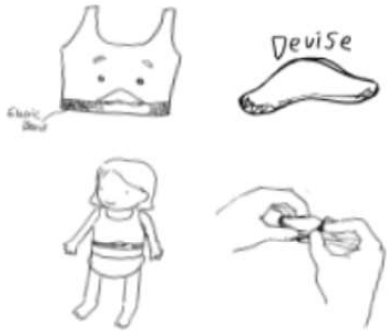
Prioritization of Design Features



일상생활 수용성	일상생활 수용성	일상생활 수용성
착용 위치	착용 위치	착용 위치
기기의 형태	기기의 형태	기기의 형태
사이즈 변경 가능성	사이즈 변경 가능성	사이즈 변경 가능성
밀착성	밀착성	밀착성
무게	무게	무게
접근성	접근성	접근성
발열여부	발열여부	발열여부
심미성	심미성	심미성
장시간 사용가능성	장시간 사용가능성	장시간 사용가능성
유해성 여부	유해성 여부	유해성 여부
재질	재질	재질
가격	가격	가격
프라이버시	프라이버시	프라이버시

Concept Evaluation

의류 타입



컨셉 1:
스포츠 브라 형태의 속옷에 기기를 장착
자유롭게 탈착 가능

투표

의견

컨셉 2:
핀형태의 기기를 기존 내의에 장착
자유롭게 탈착 가능

투표

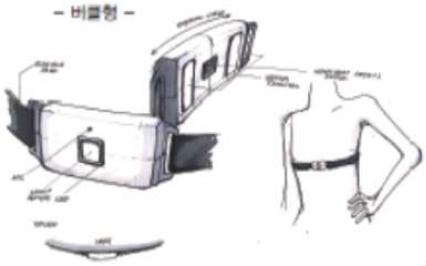
의견

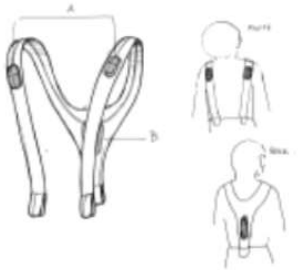
컨셉 3:
모듈화된 기기를 악세사리 형태로 장착
자유롭게 탈착 가능

투표

의견

벨트 타입





컨셉 4:
벨트형태의 기기를 가슴부위에 착용

투표

의견

컨셉 5:
기기가 장착된 벨트을 옷 안에 착용

투표

의견

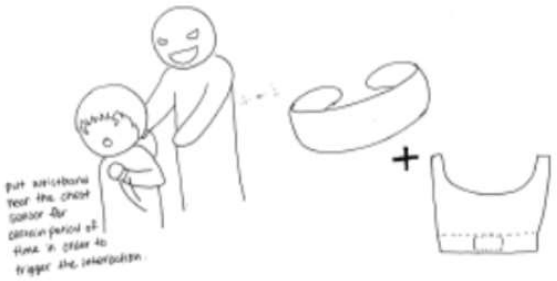
시계 타입

컨셉 6:

시계와 의류형 기기가 연동되어 있어
위험 시 특정 제스쳐를 취해 보호자에게 도움 요청

투표

의견

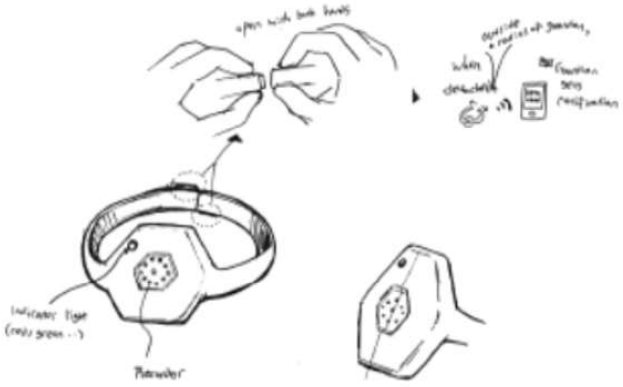


컨셉 7:

보호자가 함께 있지 않을 때 발작 시 알림.
어린이가 시계를 스스로 풀지 못하도록 함

투표

의견



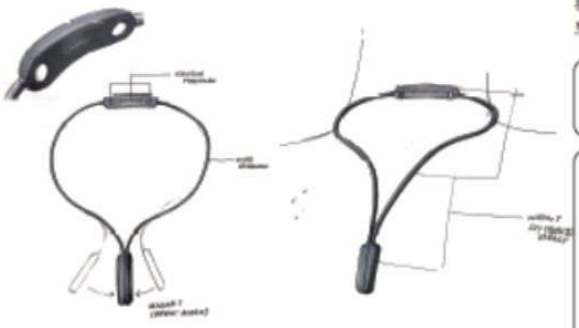
컨셉 8:

위험 감지 시 경보음 울리고 보호자에게 음성연결이 됨
경보가 울리기 전 아동이 진동을 인지하고
적절하지 않은 상황일 경우 경보가 울리지 않게 할 수 있음

투표

의견

목걸이 타입



컨셉 9:

목 뒤부분에 센서가 있고 자력을 사용하여 탈착.
보호지가 함께 있지 않을 때 탈착 시 알림

투표

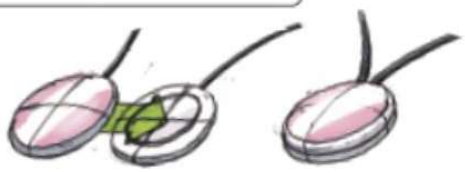
의견

컨셉 10:

사용자 맞춤형 디바이스
펜던트의 종류를 다양화하여 취향에 따라 갈아끼울 수 있음

투표

의견



컨셉 11.

사용자 맞춤형 디바이스
아동이 평소 즐겨 사용하던 기존의 목걸이에 디바이스를 부착하여 사용

투표

의견

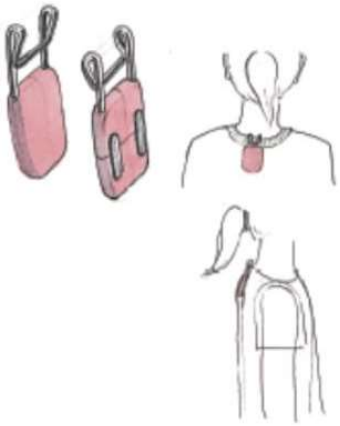
텍 타입

컨셉 12:

옷의 텍 부위에 장착

투표

의견



집게 타입

컨셉 13:
속옷 하의에 장착

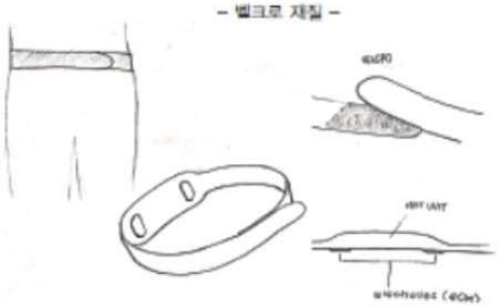
투표

의견

벨트 타입

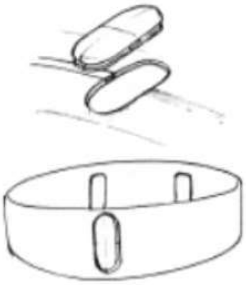
– 벨트,기기 일체형 –

– 벨크로 재질 –



컨셉 14:
벨트처럼 옷 안에 착용

– 탈착형 –



– 배가리개형 –

투표

의견

Appendix 3_Co-Design Workshop Result

Prioritization of Functional Features

FF	Expert 1	Expert 2	Expert 3	Expert 4	Mother 1	Mother 2	Total	Avg.
Location	10	10	9	10	10	8	57	9.5
Audio	9	9	10			9	37	9.25
Phone	6	8	7	9	9	10	49	8.17
Fear Detection	8		10	5	4	6	33	6.6
Posture Detection	7		8	8	2	5	30	6
Prevent removal	5		6	7	6	3	27	5.4
Alarm	4		3		7	7	21	5.25
Heart Pulse		7	5	6	3	4	25	5
Body Temp			4		5	2	11	3.67

Prioritization of Design Features

DF	Expert 1	Expert2	Expert 3	Expert 4	Mother 1	Mother 2	Total	Avg.
Everday life	15	15	15	15	8	15	83	13.83
Weight	11	14	11	11	14	13	74	12.33
Position	13		13	13	11	10	60	12
Accessibility	12		12	12	4	12	52	10.4
Affordability	10		8	10	12	11	51	10.2
Battery Life	9		14	9	7	9	48	9.6
Safety	6		6	6	15	14	47	9.4
Privacy	14		4	14	9	4	45	9
Fit-ness	8		5	8	6	6	33	6.6
Size-adjustablility	5		10	5	1	7	28	5.6
heat treatment	1		9	1	13	2	26	5.2
asthetics			7		5	3	15	5
formality	7		2	7	2	5	23	4.6
materiality	2		3	2	3	8	18	3.6

Appendix 4_Programming codes for demonstration

EDA alarm

```
// load alarm image when there is change in EDA
void draw()
{
  stroke(255);
  textSize(20);
  fill(0, 0, 255);
  //text("Number of events: ", 20, 60);
  textSize(20);
  fill(255, 255, 0);
  //text(count, 220, 60);

  if(input > max_y){
    max_y = input;
    max_x = i;
  }
  if(input < min_y){
    min_y = input;
    min_x = i;
  }
  if((max_y - min_y) > 50 && count_y == 0 && abs(max_x-min_x) >30){
    count_y = 1; // to count only one time at repeated vibration
    max_y = input;
    min_y = input;
    max_x = 0;
    min_x = 0;
    count++;
    PImage img;
    img = loadImage("loadImage.png");
    image(img, 20, 80, 410, 300);  // x, y, width, height
    tint(255);
    flag = 1;
  }
```

EDA alarm

```
68    if(input_x > max_x){
69      max_x = input_x;
70    }
71    if(input_x < min_x){
72      min_x = input_x;
73    }
74    if((max_x - min_x) > 100 && count_x1 == 0){
75      count_x1 = 1; // to count only one time at repeated vibration
76      max_x = 0;
77      min_x = 0;
78      count_x++;
79      PImage img;
80      img = loadImage("loadImage.png");
81      image(img, 120, 100, 410, 300);  // x, y, width, height
82    }
83    // x value check
84    if(input_y > max_y){
85      max_y = input_y;
86    }
87    if(input_y < min_y){
88      min_y = input_y;
89    }
90    if((max_y - min_y) > 100 && count_y1 == 0){
91      count_y1 = 1;
92      background(255,0,0);
93      max_y = 0;
94      min_y = 0;
95      PImage img;
96      img = loadImage("loadImage.png");
97      image(img, 120, 100, 410, 300);  // x, y, width, height
98    }
99    // y value check
100   if(input_z > max_z){
101     max_z = input_z;
102   }
103   if(input_z < min_z){
104     min_z = input_z;
105   }
106   if((max_z - min_z) > 100 && count_z1 == 0){
107     count_z1 = 1;
108     background(255,0,0);
109     max_y = 0;
110     min_y = 0;
111     PImage img;
112     img = loadImage("loadImage.png");
113     image(img, 120, 100, 410, 300);  // x, y, width, height
114   }
```

GPS

```
23 void draw(){
24   google_maps = loadImage
25   ("http://maps.googleapis.com/maps/api/staticmap?center=" +
26   place+
27   "&size=400x800&zoom=15&sensor=false", // url
28   "png"); // format
29   // image(google_maps, 0, 0);
30   imageMode(CENTER);
31   image(google_maps, bx, by);
32   stroke(255, 0, 0);
33   strokeWeight(10);
34   point(200, 400);
35   delay(5000);
36 }
```

Appendix 5_IRB document

Research Plan

연구계획서(인간대상연구용)

Version : 1.0

*동의설명문 변경 시 반드시 버전을 업그레이드하여 표기하여야 함.

연구과제명

아동을 상대로 한 강력 범죄 대응 디자인

연구 배경

- 선행연구 1 : 공포와 혐오 정서에 대한 아동의 심리생리 반응
  배경: 위 선행 연구는 아동이 부정적인 정서(공포와 혐오)를 느낄 때 나타나는 심리생리반응을 검증하기 위해 진행됨. 시청각 영상을 통해 정서를 유발 시킨 후 이때 나타나는 심리 반응 및 자율신경계 반응을 측정함. 이를 통해 두 정서 상태와 안정상태간의 유의미한 차이를 발견함.
- 범죄상황을 실제로 재현하기에는 윤리적 문제가 발생하기에 감정상태를 유발하는데 유효하다고 입증된 시청각 영상을 시청함으로 최소한의 위험으로 유사한 감정상태를 조성하는 방법을 사용 함.
- 본 실험은 선행연구의 도구와 측정 방법을 참고하였으며 해당 선행연구 외에도 다수의 유사한 선행연구를 발견할 수 있었음. 구조의 실험을 발견 사용 되는 장비는 비침습형 전극으로써 측정 시 인체에 유해한 영향이 없을 것으로 예상. 정서 유발 도구로 사용되는 영상물의 경우 피험자의 연령을 고려하여 영상물등급위원회로부터 전체 관람과 혹은 연소자 관람가 등급을 받은 것을 사용하여 이를 시청함으로 유발 될 수 있는 스트레스나 트라우마를 최소화 함. 운동상태 유발 도구로 사용되는 앉았다 일어서기 10 회는 정상적인 운동능력을 가진 아동이 수행하기에 무리가 없을 것으로 생각됨. 실험이 진행되는 장소 또한 아동들이 평소에 교육받는 학교의 시설을 사용함으로써 익숙하고 별다른 위험요소가 없음으로 실험 참가자에게 해가 되는 요소가 없을 것으로 생각 됨.
- 본실험을 설계함에 앞서 선행연구의 연구 책임자를 만나 인터뷰하고 실험 대상자의 안전 사항에 대한 조언을 구하였음.

연구 목적 및 필요성

- 아동들은 범죄를 인지하고 대처하는 능력이 떨어짐으로 이를 보조할 수단이 필요함. 최근들어 미아방지기기나 키즈폰과 같은 아동방범제품들이 출시되고 있음. 하지만 기존 솔루션은 위험에 대한 즉각적인 반응이 어렵고 다양한 종류의 범죄에 대응하지 못함. 아동이 위험에 처했는지를 보다 신속하고 정확하게 인지하고 대응할수 있도록 돕는 솔루션이 필요.
- 본 연구의 목표는 강력 범죄와 같은 위험한 상황에 처한 아동에게 일어나는 정황적 정보 (위치, 신체 위상, 생리 신호 등의 변화) 통해 보호자가 신속하게 대응할 수 있는 제품 혹은 서비스를 디자인하는 것임.
- 아동들이 실제 생활하는 환경에서는 공포 정서 외에도 교감신경계의 변화를 가져오는 다양한 변인들이 있음. 본 연구에서는 실험을 통해 공포, 긍정적 흥분, 운동상태가 가져오는 심리생리변화를 측정하고 비교 할 것임. 이를 통해 실생활 속에서 아동이 느끼는 공포를 얼마나 효과적으로 감지할 수 있을지에 대한 가능성을 판단할 수 있을 것으로 생각함.

연구대상자

선정 기준

- 만 8 세 아동 (초등학교 2 학년생)
  설명: 본 연구가 4 세에서 13 세 사이의 인지능력이 떨어지는 유아 및 아동을 상대로 한 것이기에 아동의 실험 참여가 불가피 함. 아동들의 연령이 다양할 경우 동일 자극에 대한 반응 정도가 크게 차이가 날 수 있어 동일 연령으로 선정.
- 구두 의사소통이 가능한 자

제외 기준

- 심신이 미약하여 실험 참가에 무리가 있다고 판단 되는 자
- 최근 정신적으로 피해를 입어 그로 인한 스트레스가 지속되고 있는 자

예상 연구대상자 수와 산출 근거

- 단일 피험자로는 학습 효과로 인해 유의미한 통계적 결과를 얻기가 어려움.
- 본 연구에서는 위의 사항들을 고려하여 피험자의 수를 20 명으로 산정함.
- 예상 연구 대상자 수는 절대적이 아니며, 계획된 연구에서 필요한 결과를 얻을 수 있는 최소한 이상의 연구 대상자 수 이어야 함

연구대상자 모집

- 피험자 모집은 모집 전단 배포를 통해 이루어질 예정.

연구대상자 동의

- 연구대상자 동의는 서면으로 이루어질 예정.

연구방법 및 설계

- 실험이 시작되기 전, 실험 진행과 절차에 대한 설명과 함께 피험자가 실험에 참가할지에 대한 여부를 다시 한번 확인
- 피험자에게 지도 교사가 실험 공간 바깥에 대기하고 있고 중간에 언제든지 실험을 참가를 거부할 수 있음을 숙지 시킴.
- 그날의 기분을 평가하는 시간을 가지며 동시에 이 시간을 통해 실험 환경에 적응하도록 함
- 주관기관의 측정장비를 사용해 ECG, GSR, IMU 를 측정. 먼저 안정상태에서 30 초간 측정한 후 정서 자극 상태를 약 2 분간 측정, 안정으로 회복되는 상태를 20 초 측정함.
- 정서 자극은 공포와 신남 두가지 이며 이 둘의 순서는 randomize 해서 실행한다.
- 운동으로 인한 신체 변화를 측정하기 위해 앉았다 일어서는 동작 10 회를 수행하고 ECG, GSR, IMU 를 측정한다. 측정 시간은 수행 동작 전 30 초와 종료 후 1 분으로 한다.
- 정서 유발에 대한 유효성 평가를 설문을 통해 5 점 척도로 평가하도록 한다.
- 획득한 신호와 설문을 S/W 를 통해 비교 분석함.

관찰 항목

- 공포 상태의 생체 신호 특성을 긍정적 흥분 상태 그리고 운동상태와 비교하여 차별성을 파악.

효과 평가 기준 및 방법

연구의 효과성을 평가하는 기준 및 방법을 기술

안전성 평가 기준 및 평가 방법

실험장비(ECG, GSR, IMU)에 의한 연구 참여자의 안전성 위험은 아직 파악된 적이 없음

앉았다 일어서는 동작 10 회는 일반적인 아동이 소화하기에 무리 없는 수준.

자료 분석과 통계적 방법

- 자가 보고에 의한 심리 평가 데이터를 분석하여 실제 유발된 정서와 일치된 정도를 평가
- 실험 종료 후 각 상태의 측정값을 MATLAB 프로그램을 통해 ANOVA 비교 분석 (안정, 공포, 신남, 운동)

예측 부작용 및 주의사항과 조치

- 본 연구는 실험 참가자에 대한 사전 필터링과 영상물 심의 등급을 준수하는 영상물 선정을 통해 피험자에게 큰 위협을 주지 않을 것으로 예상되나 영상으로 인해 과도한 공포감과 스트레스를 느낄 수 있음.
- 사전에 설문조사를 실시하여 아동들이 평소 시청하는 공포 영상물의 수위를 가늠하여 그보다 안전한 것으로 선정 함.

중지 및 탈락기준

연구자에 의해서 연구대상자의 연구 참여가 제한되는 경우 기술

연구대상자의 위험과 이익

- 실험에 참가하기 전 연구 대상자에게 유사한 영상을 시청한 경험과 이후에 신체적 혹은 정신적 이상이 있었던 경험의 여부를 확인
- 본 연구에 참여하는 연구 대상자들에게는 “피험자 보상규약”에 따라 소정의 보상이 이루어짐. 단 피험자의 연령을 고려하여 보호자들에게 대리로 지급할 예정.
- 모든 실험에는 피험자의 지도교사가 참관하여 연구 대상자의 안전을 확인
- 실험 중 긴급 상황 발생 시, 모든 실험 절차를 중지하고 피험자를 안전한 곳으로 이동시킨 후 보호자에게 즉시 연락
- 실험 후 정신적 혹은 신체적인 문제가 발생시 실험이 종료된 추후에라도 전문 의료기관에서 검진 및 치료를 받을 수 있도록 조치

연구대상자 안전대책 및 개인정보보호대책

- 연구 대상자는 본인 의사에 따라 실험 참여를 언제든지 거부할 수 있음
- 연구 대상자의 보호자 또한 언제든지 연구 대상자의 실험 참여를 거부할 수 있음
- 연구 대상자의 자발적 동의와 연구 대상자의 보호자의 동의 하에서만 실험 진행
- 실험에 대한 모든 정보는 외부로 유출 되지 않으며 연구책임자와 지도 교수만 열람이 가능하도록 보관

참고문헌

장은혜 et al. (2007) 동영상 자극에 의해 유발된 혐오와 공포에 따른 자율신경계 반응 : 초등학생을 대상으로, *한국감성과학회, Vol. 10 No. 2, 273-280*

Krupa, N., Anantharam, K., Sanker, M., Datta, S., & Sagar, J. V. (2016). Recognition of emotions in autistic children using physiological signals. *Health and Technology*, 1-11.

Education Certificate

CERTIFICATE OF COMPLETION

CITI KOREA | Collaborative Institutional Training Initiative Program

The Collaborative Institutional Training Initiative(CITI) Program
at the University of Miami

We present this certificate to

Kido Chang

Ulsan National Institute of Science and Technology

In recognition of successful completion of the requirements for

Health Information Privacy and Security (HIPS)

Completion Report No. : K-2016-21088334
Date Completed : October 6, 2016
Year of Birth : 1984

Paul G. Braunschweiger, Ph.D.
Professor
University of Miami
CITI Program Co-founder

B. I. Choe, M.B.A., LL.M., Ph.D.
Professor of Bioethics
The Catholic University of Korea
CITI-KOREA Program Director

CERTIFICATE OF COMPLETION

CITI KOREA | Collaborative Institutional Training Initiative Program

The Collaborative Institutional Training Initiative(CITI) Program
at the University of Miami

We present this certificate to

Kido Chang

Ulsan National Institute of Science and Technology

In recognition of successful completion of the requirements for

Biomedical Research

Completion Report No. : K-2016-21088333
Date Completed : October 6, 2016
Year of Birth : 1984

Paul G. Braunschweiger, Ph.D.
Professor
University of Miami
CITI Program Co-founder

B. I. Choe, M.B.A., LL.M., Ph.D.
Professor of Bioethics
The Catholic University of Korea
CITI-KOREA Program Director

Appendix 6_Patent document

관 인 생 략

출 원 번 호 통 지 서

출 원 일 자	2016.07.11
특 기 사 항	심사청구(유) 공개신청(무)
출 원 번 호	10-2016-0087371 (접수번호 1-1-2016-0667012-14)
출원인 명칭	울산과학기술원(1-2015-081204-7)
대리인 성명	특허법인 무한(9-2007-100061-4)
발명자 성명	백준상 장기도 박윤이 이안 오클리 이해랑 김준태 도승헌
발명의 명칭	사용자의 심적 안정도를 모니터링하는 단말, 웨어러블 디바이스, 및 방법

특 허 청 장

<< 안내 >>

1. 귀하의 출원은 위와 같이 정상적으로 접수되었으며, 이후의 심사 진행상황은 출원번호를 통해 확인하실 수 있습니다.

2. 출원에 따른 수수료는 접수일로부터 다음날까지 동봉된 납입영수증에 성명, 납부자번호 등을 기재하여 가까운 우체국 또는 은행에 납부하여야 합니다.
※ 납부자번호 : 0131(기관코드) + 접수번호

3. 귀하의 주소, 연락처 등의 변경사항이 있을 경우, 즉시 [출원인코드 정보변경(경정), 정정신고서]를 제출하여야 출원 이후의 각종 통지서를 정상적으로 받을 수 있습니다.
※ 특허로(patent.go.kr) 접속 > 민원서식다운로드 > 특허법 시행규칙 별지 제5호 서식

4. 특허(실용신안등록)출원은 명세서 또는 도면의 보정이 필요한 경우, 등록결정 이전 또는 의견서 제출기간 이내에 출원서에 최초로 첨부된 명세서 또는 도면에 기재된 사항의 범위 안에서 보정할 수 있습니다.

5. 외국으로 출원하고자 하는 경우 PCT 제도(특허·실용신안)나 마드리드 제도(상표)를 이용할 수 있습니다. 국내출원일을 외국에서 인정받고자 하는 경우에는 국내출원일로부터 일정한 기간 내에 외국에 출원하여야 우선권을 인정받을 수 있습니다.
※ 제도 안내 : http://www.kipo.go.kr-특허마당-PCT/마드리드
※ 우선권 인정기간 : 특허·실용신안은 12개월, 상표·디자인은 6개월 이내
※ 미국특허상표청의 선출원을 기초로 우리나라에 우선권주장출원 시, 선출원이 미공개상태이면, 우선일로부터 16개월 이내에 미국특허상표청에 [전자적교환허가서(PTO/SB/39)를 제출하거나 우리나라에 우선권 증명서류를 제출하여야 합니다.

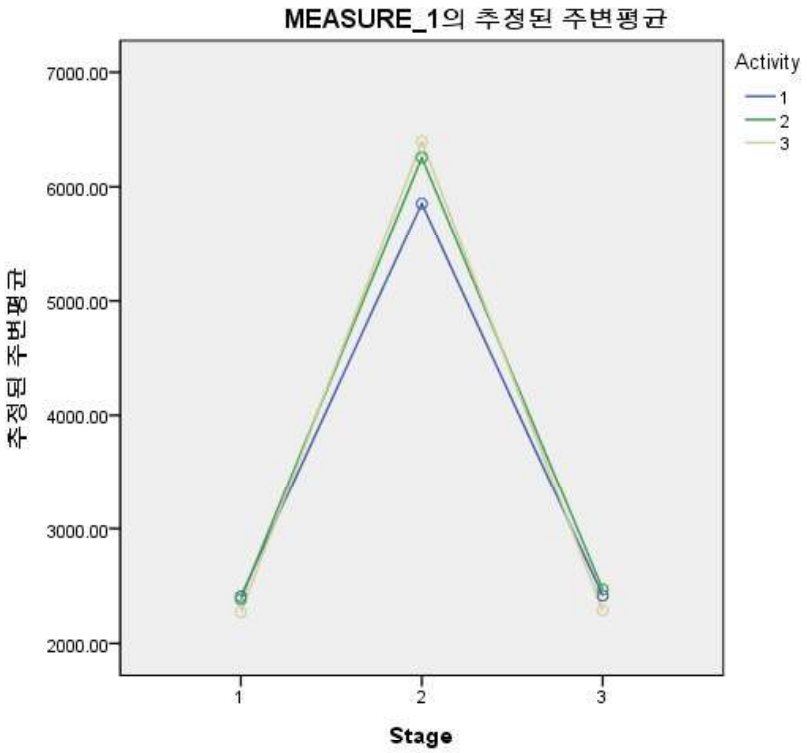
6. 본 출원사실을 외부에 표시하고자 하는 경우에는 아래와 같이 하여야 하며, 이를 위반할 경우 관련법령에 따라 처벌을 받을 수 있습니다.
※ 특허출원 10-2010-0000000, 상표등록출원 40-2010-0000000

7. 종업원이 직무수행과정에서 개발한 발명을 사용자(기업)가 명확하게 승계하지 않은 경우, 특허법 제62조에 따라 심사단계에서 특허거절결정되거나 특허법 제133조에 따라 등록이후에 특허무효사유가 될 수 있습니다.

8.기타 심사 절차에 관한 사항은 동봉된 안내서를 참조하시기 바랍니다.

Appendix 7 Repeated-measure ANOVA on ECG and EDA data

ECG_Mean

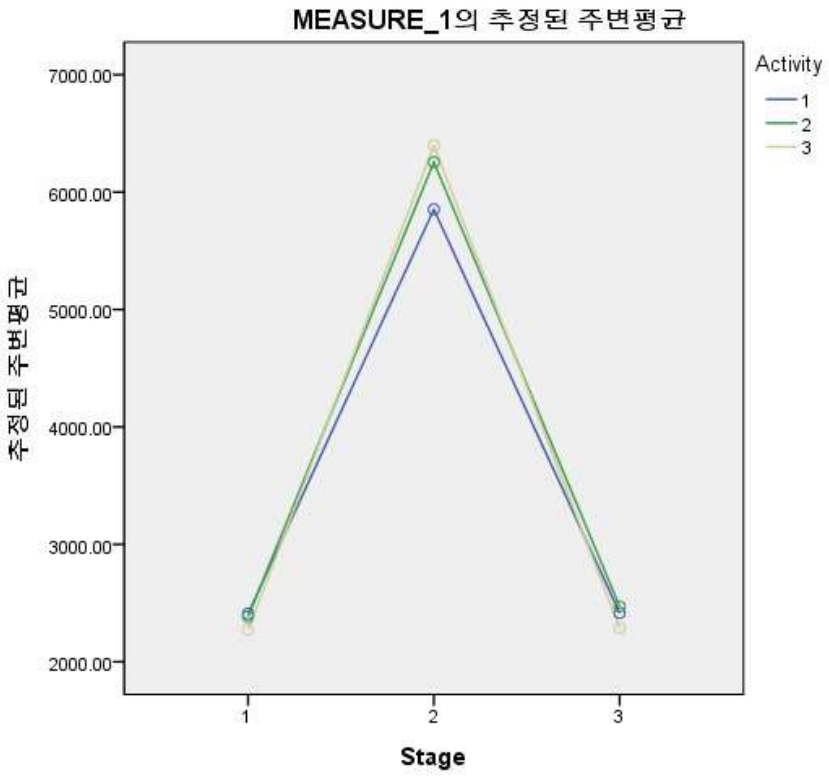


개체-내 효과 검정

측도: MEASURE_1

소스		제 III 유형 제곱합	자유도	평균 제곱	F	유의확률
Activity	구형성 가정	289427.556	2	144713.778	1.203	.326
	Greenhouse-Geisser	289427.556	1.672	173083.203	1.203	.322
	Huynh-Feldt	289427.556	2.000	144713.778	1.203	.326
	하한값	289427.556	1.000	289427.556	1.203	.305
오차(Activity)	구형성 가정	1924490.733	16	120280.671		
	Greenhouse-Geisser	1924490.733	13.377	143860.274		
	Huynh-Feldt	1924490.733	16.000	120280.671		
	하한값	1924490.733	8.000	240561.342		
Stage	구형성 가정	259218718.1	2	129609359.1	338.512	.000
	Greenhouse-Geisser	259218718.1	1.744	148609962.7	338.512	.000
	Huynh-Feldt	259218718.1	2.000	129609359.1	338.512	.000
	하한값	259218718.1	1.000	259218718.1	338.512	.000
오차(Stage)	구형성 가정	6126068.205	16	382879.263		
	Greenhouse-Geisser	6126068.205	13.954	439008.984		
	Huynh-Feldt	6126068.205	16.000	382879.263		
	하한값	6126068.205	8.000	765758.526		
Activity * Stage	구형성 가정	1398398.620	4	349599.655	1.096	.375
	Greenhouse-Geisser	1398398.620	2.587	540474.104	1.096	.366
	Huynh-Feldt	1398398.620	3.933	355584.134	1.096	.375
	하한값	1398398.620	1.000	1398398.620	1.096	.326
오차(Activity*Stage)	구형성 가정	10206054.21	32	318939.194		
	Greenhouse-Geisser	10206054.21	20.699	493073.642		
	Huynh-Feldt	10206054.21	31.461	324398.824		
	하한값	10206054.21	8.000	1275756.776		

ECG_STD

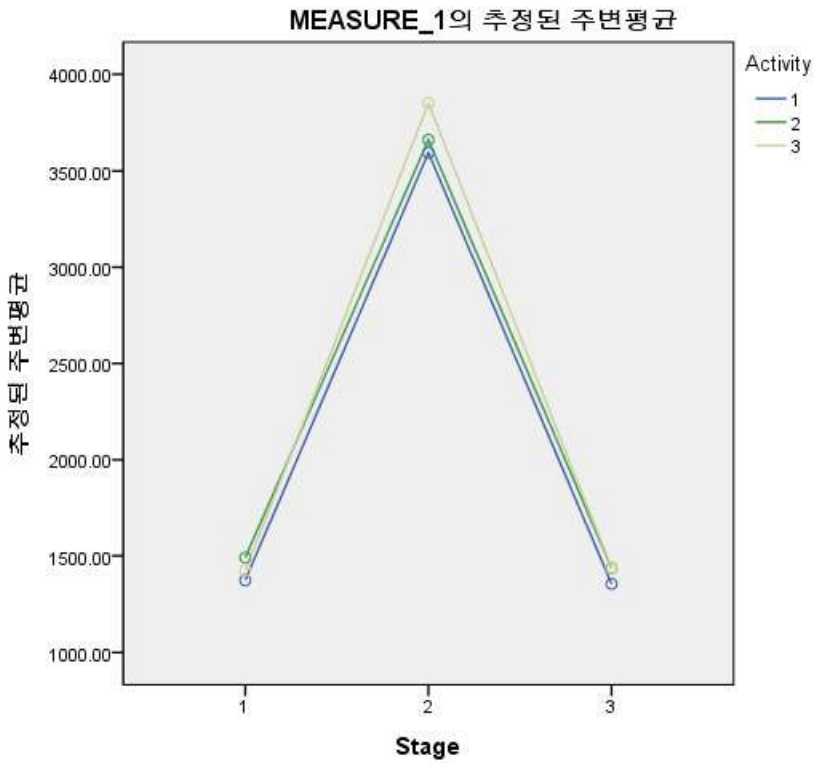


개체-내 효과 검정

측도: MEASURE_1

소스		제 III 유형 제곱합	자유도	평균 제곱	F	유의확률
Activity	구형성 가정	238358.038	2	119179.019	1.537	.245
	Greenhouse-Geisser	238358.038	1.223	194879.002	1.537	.251
	Huynh-Feldt	238358.038	1.329	179321.933	1.537	.251
	하한값	238358.038	1.000	238358.038	1.537	.250
오차(Activity)	구형성 가정	1240311.755	16	77519.485		
	Greenhouse-Geisser	1240311.755	9.785	126758.216		
	Huynh-Feldt	1240311.755	10.634	116639.187		
	하한값	1240311.755	8.000	155038.969		
Stage	구형성 가정	93808509.63	2	46904254.81	316.397	.000
	Greenhouse-Geisser	93808509.63	1.075	87245432.46	316.397	.000
	Huynh-Feldt	93808509.63	1.109	84616428.23	316.397	.000
	하한값	93808509.63	1.000	93808509.63	316.397	.000
오차(Stage)	구형성 가정	2371921.868	16	148245.117		
	Greenhouse-Geisser	2371921.868	8.602	275747.038		
	Huynh-Feldt	2371921.868	8.869	267437.833		
	하한값	2371921.868	8.000	296490.234		
Activity * Stage	구형성 가정	182859.742	4	45714.936	.604	.663
	Greenhouse-Geisser	182859.742	1.654	110583.319	.604	.531
	Huynh-Feldt	182859.742	2.030	90084.811	.604	.561
	하한값	182859.742	1.000	182859.742	.604	.459
오차(Activity*Stage)	구형성 가정	2422794.196	32	75712.319		
	Greenhouse-Geisser	2422794.196	13.229	183146.261		
	Huynh-Feldt	2422794.196	16.239	149196.971		
	하한값	2422794.196	8.000	302849.274		

ECG_RMS

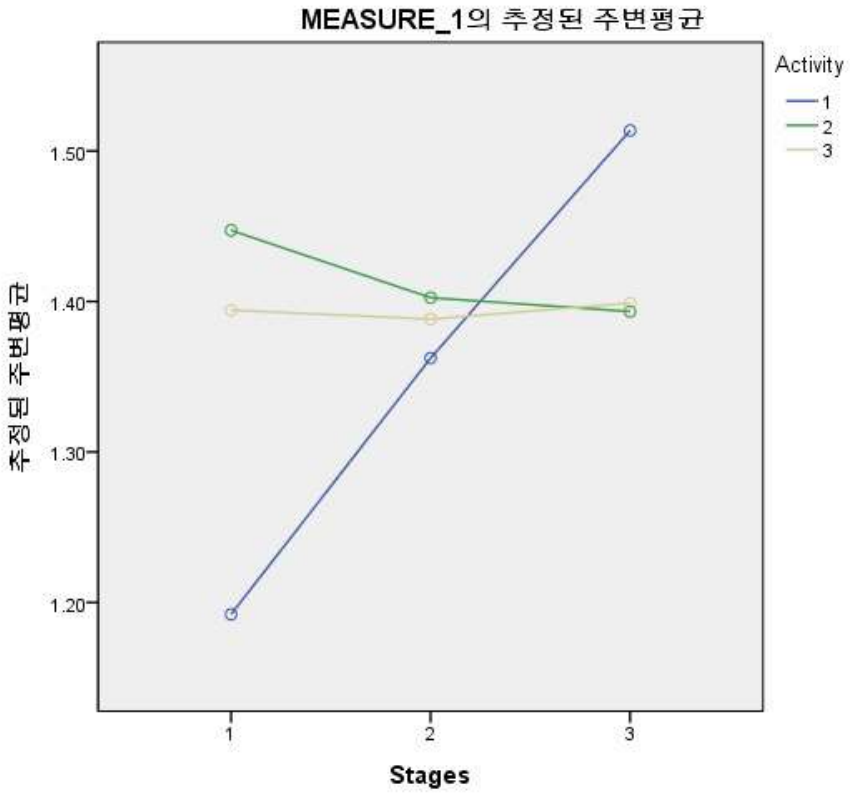


개체-내 효과 검정

측도: MEASURE_1

소스		제 III 유형 제곱합	자유도	평균 제곱	F	유의확률
Activity	구형성 가정	238358.038	2	119179.019	1.537	.245
	Greenhouse-Geisser	238358.038	1.223	194879.002	1.537	.251
	Huynh-Feldt	238358.038	1.329	179321.933	1.537	.251
	하한값	238358.038	1.000	238358.038	1.537	.250
오차(Activity)	구형성 가정	1240311.755	16	77519.485		
	Greenhouse-Geisser	1240311.755	9.785	126758.216		
	Huynh-Feldt	1240311.755	10.634	116639.187		
	하한값	1240311.755	8.000	155038.969		
Stage	구형성 가정	93808509.63	2	46904254.81	316.397	.000
	Greenhouse-Geisser	93808509.63	1.075	87245432.46	316.397	.000
	Huynh-Feldt	93808509.63	1.109	84616428.23	316.397	.000
	하한값	93808509.63	1.000	93808509.63	316.397	.000
오차(Stage)	구형성 가정	2371921.868	16	148245.117		
	Greenhouse-Geisser	2371921.868	8.602	275747.038		
	Huynh-Feldt	2371921.868	8.869	267437.833		
	하한값	2371921.868	8.000	296490.234		
Activity * Stage	구형성 가정	182859.742	4	45714.936	.604	.663
	Greenhouse-Geisser	182859.742	1.654	110583.319	.604	.531
	Huynh-Feldt	182859.742	2.030	90084.811	.604	.561
	하한값	182859.742	1.000	182859.742	.604	.459
오차(Activity*Stage)	구형성 가정	2422794.196	32	75712.319		
	Greenhouse-Geisser	2422794.196	13.229	183146.261		
	Huynh-Feldt	2422794.196	16.239	149196.971		
	하한값	2422794.196	8.000	302849.274		

EDA_Mean

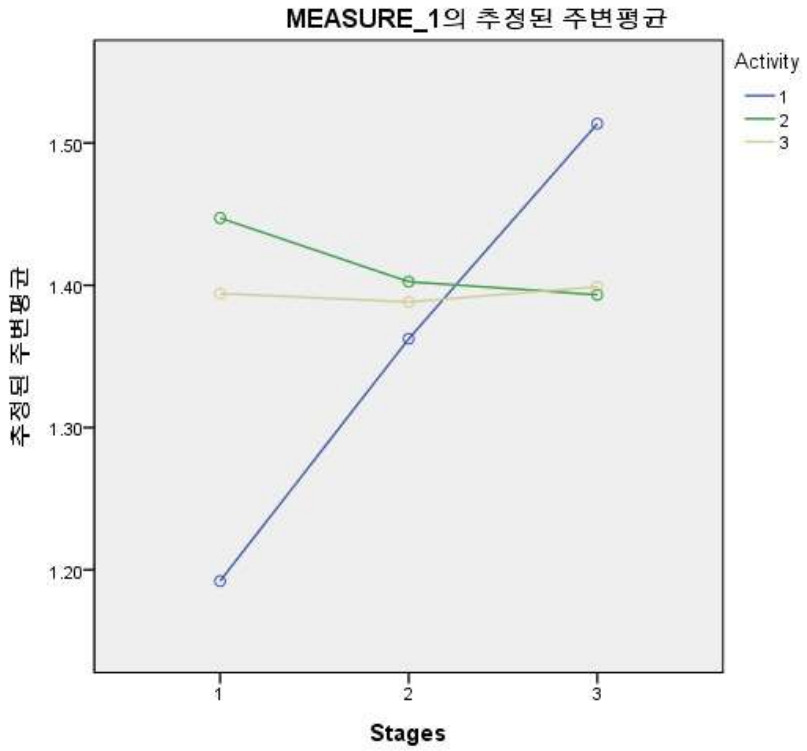


개체-내 대비 검정

측도: MEASURE_1

소스	Activity	Stages	제 III 유형 제곱합	자유도	평균 제곱	F	유의확률
Activity	선형모형		.019	1	.019	.233	.642
	2차모형		.028	1	.028	.408	.541
오차(Activity)	선형모형		.661	8	.083		
	2차모형		.550	8	.069		
Stages		선형모형	.111	1	.111	2.886	.128
		2차모형	.001	1	.001	.052	.826
오차(Stages)		선형모형	.308	8	.039		
		2차모형	.084	8	.011		
Activity * Stages	선형모형	선형모형	.226	1	.226	4.476	.067
		2차모형	.001	1	.001	.097	.764
	2차모형	선형모형	.141	1	.141	3.036	.120
		2차모형	.001	1	.001	.176	.686
오차(Activity*Stages)	선형모형	선형모형	.404	8	.050		
		2차모형	.079	8	.010		
	2차모형	선형모형	.372	8	.047		
		2차모형	.061	8	.008		

EDA_STD

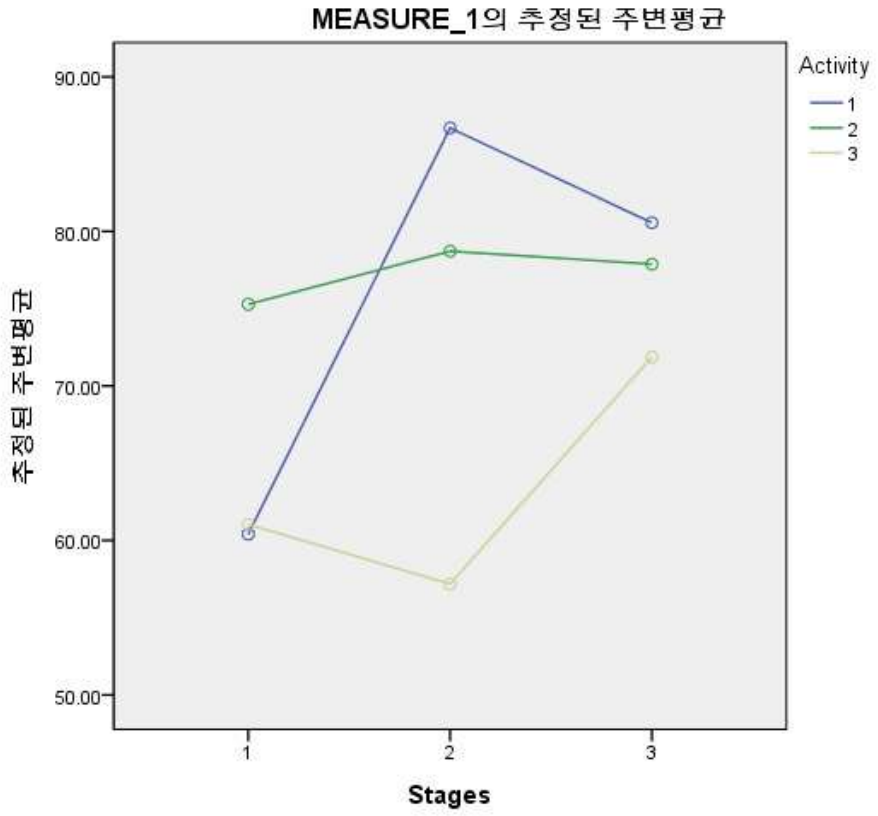


개체-내 대비 검정

측도: MEASURE_1

소스	Activity	Stages	제 III 유형 제곱합	자유도	평균 제곱	F	유의확률
Activity	선형모형		.019	1	.019	.233	.642
	2차모형		.028	1	.028	.408	.541
오차(Activity)	선형모형		.661	8	.083		
	2차모형		.550	8	.069		
Stages		선형모형	.111	1	.111	2.886	.128
		2차모형	.001	1	.001	.052	.826
오차(Stages)		선형모형	.308	8	.039		
		2차모형	.084	8	.011		
Activity * Stages	선형모형	선형모형	.226	1	.226	4.476	.067
		2차모형	.001	1	.001	.097	.764
	2차모형	선형모형	.141	1	.141	3.036	.120
		2차모형	.001	1	.001	.176	.686
오차(Activity*Stages)	선형모형	선형모형	.404	8	.050		
		2차모형	.079	8	.010		
	2차모형	선형모형	.372	8	.047		
		2차모형	.061	8	.008		

EDA_CR



개체-내 대비 검정

측도: MEASURE_1

소스	Activity	Stages	제 III 유형 제곱합	자유도	평균 제곱	F	유의확률
Activity	선형모형		2116.569	1	2116.569	3.054	.119
	2차모형		1058.880	1	1058.880	2.029	.192
오차(Activity)	선형모형		5544.625	8	693.078		
	2차모형		4175.851	8	521.981		
Stages		선형모형	1693.840	1	1693.840	6.805	.031
		2차모형	164.612	1	164.612	.321	.587
오차(Stages)		선형모형	1991.208	8	248.901		
		2차모형	4104.111	8	513.014		
Activity * Stages	선형모형	선형모형	195.123	1	195.123	.289	.606
		2차모형	1948.560	1	1948.560	5.497	.047
	2차모형	선형모형	499.514	1	499.514	.834	.388
		2차모형	7.078	1	7.078	.012	.915
오차(Activity*Stages)	선형모형	선형모형	5408.834	8	676.104		
		2차모형	2835.667	8	354.458		
	2차모형	선형모형	4791.659	8	598.957		
		2차모형	4614.866	8	576.858		

Executive Summer in Korean

아동 대상 강력 범죄를 위한 웨어러블 디자인

이 프로젝트의 목적은 아동을 상대로 한 강력 범죄를 해결하는 솔루션을 개발하는 것입니다. 프로젝트의 전반적인 프로세스는 디자인 대상에 대한 포괄적인 이해를 얻기 위한 사전연구로 시작됩니다.

도입단계인 사전연구에서는 주제에 대한 연구 보고서 및 문헌과 실제 범죄 사례 수집 및 분석, 전문가 인터뷰 등이 이뤄졌습니다. 그 결과 피해자가 겪게 되는 일련의 경험과 그에 대한 통합적인 프레임워크가 만들어졌으며 아동에 대한 범죄의 특징과 패턴을 이해하고 파악할 수 있었습니다. 아동은 범죄를 인식하고 대응하는 능력이 성인보다 훨씬 약하고 정확하고 충분한 증언을 하는 데 종종 어려움을 겪습니다. 범죄자들은 이러한 취약점을 이용하기 때문에 아동을 상대로 한 범죄는 쉽게 은폐되고 상습적이 된다는 것을 알 수 있었습니다. 예비 연구의 목적으로 현재 시장에 나와 있는 솔루션에 대한 벤치마킹이 수행되었습니다. 기존 솔루션의 문제점은 그 사용 방법에 있어서 사용자의 판단과 반응에 크게 의존한다는 점이었는데, 아동은 이 부분에 약점을 가지고 있으므로 새로운 방식이 필요해 보였습니다.

사전 연구의 결과를 바탕으로 디자인 목표를 설정하였습니다. 첫 번째 목표는 아동의 대응을 돕는 것이고 두 번째는 보호자가 사건에 대해 인지하도록 하는 것입니다. 전문가 인터뷰 중 한 경찰관은 본인이 봐온 12 세 미만의 아동범죄 사건에서 대부분 아동은 범죄 상황을 마주할 때 그냥 울어버리고 적합한 대응을 하지 못한다고 말했습니다. 이 프로젝트의 대상 사용자는 5 세에서 12 세 사이의 아동으로 설정되었습니다.

범죄를 감지하는 데 필요한 일련의 Data set을 발견하는 것이 중요합니다. 웨어러블 기기를 사용하면 다양한 종류의 센서를 통해 사용자의 상태에 대해 정보를 수집할 수 있습니다. 기존에 존재하는 웨어러블 기기들은 GPS 나 IMU 와 같은 정보만으로 알 수 없는 상황을 감지하기 위해서 생체 신호를 사용하기도 합니다. 생체 신호와 가속도 센서 등의 정보를 함께 사용해서 간질 발작이나 우는 아기와 같은 상황도 인지해 내는 데 성공했습니다. 이 프로젝트에서는 아동에게 일어날 수 있는 범죄 상황을 파악하는 데 가장 효과적인 Data set 을 찾아야 했습니다.

이 Data set 을 발견하기 위해 코디자인 방법론이 사용되었습니다. 워크숍 형태로 진행된 이 과정에는 4 명의 전문가와 2 명의 어머니를 포함한 이해관계자들이 한자리에 모여 아동이 처한 위험을 감지하는 데 필요한 Data set 을 고민하고 이러한 목적을 가진 제품이 지녀야 할 기능과 및 형태에 대한 우선순위를 정리하는 시간을 가졌습니다.

워크숍의 결과를 통해 아동 범죄를 감지하는 데 필요한 Data Set 을 규명하였고 다음과 같습니다. 1. 감정 인식 정보 (생리적 신호) 2. 위치정보 3. 신체의 움직임 및 자세. 이 세 종류의 정보를 조합하여 사용자가 위험에 처했음을 감지하면 보호자에게 알림을 보내게 됩니다. 알림을 받은 보호자는 비디오 및 오디오 정보를 통해 아동의 상태를 확인할 수 있습니다.

코디자인 워크숍의 결과를 토대로 아이디에이션이 진행이 되었는데 이를 위해 벤치마킹, 무드 보드, 스케치, 소프트 프로토타이핑 등의 방법들이 사용되었습니다. 아이디어의 최종 선택은 두 명의 교수와 세 명의 연구원의 자문을 통해 이루어졌습니다.

본 제품 서비스 시스템은 아동이 착용하는 웨어러블 기기, 그리고 이를 사용하기 위한 스마트 디바이스용 애플리케이션으로 구성되어 있습니다. 웨어러블 디바이스는 아동의 위치, 자세 및 생체 신호를 지속해서 감지합니다. 아동에게서 수집되는 정보에서 이상이 감지되는 경고 알림이 보호자에게 보내지게 되고 아동의 상태를 확인하도록 권유하게 됩니다. 보호자는 알림을 통해 현재 아동이 있는 위치, 자세 및 감정 데이터에 어떤 이상이 있는지를 바탕으로 현재 아동이 실제로 위험에 처했을지를 추론할 수 있습니다. 만약에 아동의 안전을 확인해야 한다고 판단하면 곧바로 화상 통화를 통해 자녀의 상태를 확인할 수 있습니다. 후속 조치는 보호자의 재량에 따라 이루어질 수 있습니다.

프로젝트 과정 중에는 두 가지 워킹 프로토타입이 제작되었습니다. 하나는 컨셉 검증을 위한 사용자 실험 용이고 다른 하나는 컨셉을 설명하고 전시하기 위한 것입니다. 사용자 실험은 총 11 명의 8 세 아동들이 참가하였습니다. 실험의 목표는 EDA 와 ECG 를 이용한 공포감지 시스템이 아이들의 일상 환경에서 유효한지 알아보는 것이었습니다. 설정된 4 개의 조건에서 3 개 유형의 데이터 (EDA / ECG / Acceleration in Motion)를 수집했습니다. 감정 유발은 기존 연구에서 사용한 방법(장은혜 et al., 2007)인 시청각 영상물을 통한 감정 자극을 통해 진행되었습니다. 결과를 분석하였을 때 일상생활 속에서 생리적 신호를 통해 감정은 인지할 가능성을 발견할 수 있었습니다. 육안 검사 분석을 통해서 평안, 운동, 신남, 신호를 구별할 수 있었으며 Repeated-measure ANOVA 분석을 통해서는 EDA 와 ECG 를 통해 자극이 효과적이었음을 알 수 있었습니다.

도출된 솔루션의 장점은 사용자가 신속하고 정확하게 위험 상황을 인지하고 반응할 수 있다는 점입니다. 하지만 개인으로 진행된 본 프로젝트의 명확한 한계점은 데이터 처리를 위해 더욱 많은 전문 인력 간의 협업이 필요하다는 점입니다. 개인마다 가지고 있는 고유의 생활방식과 생체 데이터 패턴을 학습하고 이에 대한 정확한 데이터 해석을 하기 위해서는 빅데이터와 딥러닝, 그리고 임상 심리 등의 전문 지식과 기술이 필요합니다. 유사한 기술의 제품을 개발하는 기업의 인적자원을 살펴보면 대부분 인력이 엔지니어와 데이터 과학자임을 알 수 있습니다. 본 프로젝트가 앞으로도 진행되기 위해서는 팀워크가 되어야 할 것입니다.

핵심어: 아동 범죄, 웨어러블, 코디자인, 감정 인식

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저를 창조하시고 매일매일 새로운 숨을 불어넣어 주시는 하나님께 감사를 드립니다. 하나님은 제가 살아가는 이유이시자 학문의 주제이시며 도달할 목적지이십니다.

단언컨대 UNIST 에 오고 난 뒤 가장 감사한 것은 백준상 교수님을 만난 것입니다. 교수님을 통해 학자가 지녀야 할 자세와 삶에 대한 정직한 태도를 배울 수 있었습니다. 엄밀한 연구한 무엇인지에 대해서 가르쳐 주셨고 수평적이고 열린 토론을 통해 지도해 주셨습니다. 그러면서도 진심으로 저희 지도 학생들을 사랑하고 아껴주셨습니다. 그런 교수님을 참으로 존경합니다.

본 프로젝트의 결과물이 나올 수 있도록 아낌없이 조언해 주시고 격려해 주셨던 이안 오클리 교수님, 자문을 요청하면 늘 상냥하고 흔쾌히 응해 주신 권오상 교수님, 생체신호는 일단 눈으로 확인해야 한다는 중요한 말씀을 해주신 김성필 교수님 감사드립니다. 헌신적으로 프로토타이핑을 도와주었던 제호와 재호네 가족에게 감사합니다. 그리고 마지막 순간까지도 데이터 분석을 도와준 훌륭한 성균이 형에게도 고맙습니다.

DESIS 의 보물 소정이와 윤이에게 고맙다고 말하고 싶습니다. 이 사람들 없는 연구실 생활은 상상도 하기 싫을 정도로 귀한 동료이자 식구였습니다. 두 사람의 긍정적인 태도와 발랄함으로 인해서 2 년 동안 UNIST 에서 정말로 행복했습니다.

세상을 살아갈 방향과 방법을 가르쳐 주시고 지금의 제가 있도록 도와주신 부모님, 늘 응원해주는 사랑이네 가족에게 감사합니다. 이분들은 세상 앞에 디디고 설 토양이 되어주었습니다.

마지막으로 늘 옆에서 제게 힘이 되어주었던 나의 사랑하는 약혼자 지수에게도 고맙습니다. 앞으로도 어떤 상황에서도 서로를 향한 신뢰를 잃어버리지 않고 같이 갔으면 좋겠습니다.

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Wearable Design for Violent Crime against Children